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	Name & Function	Signature	Date
Prepared by:	Laplena D. (PA/SF)		
Approved by: ✗	Laplena D. (PA/SF/)		21/03/05
	Cinquepalmi C. (PA/CC)		21/01/05
	G. Magistrati (IU/SE)		21/01/05
	M. Grilli (IU/SE)		21/01/05
Application authorized by:	Pini C. (IU/PM)		21.01.05

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1	January 2005		First Issue for PDR

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ACRONYMS AND ABBREVATIONS

A
AAA   Avionics Air Assembly
ABCL   As-Built Configuration data List
ACOP   AMS-02 Crew Operation Post
ACOP-SW   ACOP Flight Software
ADP   Acceptance Data Package
AMS-02   Alpha Magnetic Spectrometer 02
APS   Automatic Payload Switch
AR   Acceptance Review
ASI   Agenzia Spaziale Italiana *(Italian Space Agency)*
ATP   Authorization To Proceed

B
BC   Bus Coupler
BDC   Baseline Data Collection
BDCM   Baseline Data Collection Model

C
CAD   Computer Aided Design
CCB   Configuration Control Board
CCSDS   Consultative Committee on Space Data Standards (standard format for data transmission)
C&DH   Command & Data Handling
CDR   Critical Design Review
CGS   Carlo Gavazzi Space
CI   Configuration Item
CIDL   Configuration Item data List
CM   Configuration Management
COTS   Commercial Off The Shelf
cPCI   CompactPCI (Euro Card sized standard interface to the PCI)
CSCI   Computer Software Configuration Item
CSIST   Chung Shan Institute of Science and Technology

D
DCL   Declared Components List
DIL   Deliverable Items List
DIO   Digital Input / Output
DML   Declared Materials List
DMPL   Declared Mechanical Parts List
DPL   Declared Processes List
DRB   Delivery Review Board
DRD   Document Requirements Description

E
EEE   Electrical, Electronic & Electromechanical
EGSE   Electrical Ground Support Equipment
EM   Engineering Model
ER   EXPRESS Rack
ERL   EXPRESS Rack Laptop
ERLC   EXPRESS Rack Laptop Computer
ERLS   EXPRESS Rack Laptop Software
EMC   Electro-Magnetic Compatibility
ESA   European Space Agency
EXPRESS   EXpedite the PRocessing of Experiments to Space Station

F
FEM   Finite Element Model
FFMAR   Final Flight Model Acceptance Review

FLASH   Rewriteable persistent computer memory
FM   Flight Model
FMECA   Failure Modes, Effects & Criticalities Analysis
FPGA   Field Programmable Gate Array
FSM   Flight Spare Model

G
GIDEP   Government Industry Data Exchange Program
GSE   Ground Support Equipment

H
HCOR   HRDL Communications Outage Recorder
HD   Hard Drive
HDD   Hard Disk Drive
HRDL   High Rate Data Link
HRFM   High Rate Frame Multiplexer
HW   Hardware

I
ICD   Interface Control Document
I/F   Interface
IRD   Interface Requirements Document
ISPR   International Space-station Payload Rack
ISS   International Space Station

J
JSC   Johnson Space Center

K
KIP   Key Inspection Point
KSC   Kennedy Space Center
KU-Band   High rate space to ground radio link

L
LAN   Local Area Network
LCD   Liquid Crystal Display
LFM   Low Fidelity Model
LRDL   Low Rate Data Link

M
MDL   Mid-Deck Locker
MGSE   Mechanical Ground Support Equipment
MIP   Mandatory Inspection Point
MMI   Man Machine Interface
MPLM   Multi-Purpose Logistic Module
MRDL   Medium Rate Data Link

N
NA   Not Applicable
NASA   National Aeronautics and Space Administration
NCR   Non Conformance Report
NDI   Non Destructive Inspection
NRB   Non-conformance Review Board
NSTS   National Space Transportation System (Shuttle)

O
OLED   Organic Light-Emitting Diode
ORU   Orbital Replacement Unit

P
PA   Product Assurance
PCB   Printed Circuit Board
PCI   Peripheral Component Interconnect (personal computer bus)

PCS   Personal Computer System
PDR   Preliminary Design Review
PEHB   Payload Ethernet Hub Bridge
PEHG   Payload Ethernet Hub Gateway
PFMAR   Preliminary Flight Model Acceptance Review
PLMDM   Payload Multiplexer De-Multiplexer
PMC   PCI (Peripheral Component Interconnect) Mezzanine Card
PMP   Parts, Materials & Processes
PROM   Programmable Read Only Memory
PS   Power Supply

Q
QM   Qualification Model

R
RFA   Request For Approval
RFD   Request For Deviation
RFW   Request For Waiver
RIC   Rack Interface Controller
ROD   Review Of Design
ROM   Read Only Memory
RX   Reception

S
SATA   Serial Advanced Transfer Architecture (disk interface)
S-Band   Space to ground radio link
SBC   Single Board Computer
SC MDM   Station Control Multiplexer De-Multiplexer
ScS   Suitcase Simulator
SDD   Solid-state Disk Drive
SIM   Similarity Assessment
SIO   Serial Input Output
SOW   Statement Of Work
SPF   Single Point Failure
SRD   Software Requirements Document
STS   Space Transportation System (Shuttle)
SW   Software

T
TBC   To Be Confirmed
TBD   To Be Defined
TBDCM   Training & Baseline Data Collection Model
TBDCMAR   TBDCM Acceptance Review
TBP   To Be Provided
TCP/IP   Transmission Control Protocol / Internet Protocol
TFT   Thin Film Transistor
TM   Telemetry
TRB   Test Review Board
TRR   Test Readiness Review
TRM   Training Model
TX   Transmission

U
UIP   Utility Interface Panel
UMA   Universal Mating Assembly
USB   Universal Serial Bus

#
100bt   Ethernet 100Mbit Specification
1553   Reliable serial communications bus

1. INTRODUCTION

1.1   PURPOSE

The scope of this document is to provide the results coming from Failure Modes, Effects and Criticality Analysis (FMECA), carried out on the ACOP.

The FMECA identifies all failures and modes of failure that can occur at ACOP and investigates the resulting performance and effects on system and mission success as well as the possible failure prevention and compensation methods. The Consequence Severity Categories has been assigned to each failure mode according to the severity of the potential observed failure effect on ACOP. The FMECA has been performed according to GPQ-010-PSA-102 [RD 8].
The analysis has been performed on the design at its current status, in the frame of PDR.

2. DOCUMENTS

2.1 APPLICABLE DOCUMENTS

AD	Doc. Number	Issue / Date	Rev.	Title / Applicability
1	SSP 52000-IDD-ERP	D / 6/08/03		EXpedite the PRocessing of Experiments to Space Station (EXPRESS) Rack Payloads Interface Definition Document
2	NSTS/ISS 13830	C / 01/12/1996		Implementation Procedures for Payloads System Safety Requirements – For Payloads Using the STS & ISS.
3	JSC 26493	17/02/1995		Guidelines for the preparation of payload flight safety data packages and hazard reports.
4	SSP 50004	April 1994		Ground Support Equipment Design requirements
5	SSP-52000-PDS	March 1999	B	Payload Data Set Blank Book
6	SSP 52000-EIA-ERP	Feb. 2001	A	Express Rack Integration Agreement blank book for Express Rack payload
7	GD-PL-CGS-001	3 / 17/03/99		PRODUCT ASSURANCE & RAMS PLAN
8	SSP 52000 PAH ERP	Nov. 1997		Payload Accommodation Handbook for EXPRESS Rack
9	SSP 50184	D / Feb. 1996		Physical Media, Physical Signaling & link-level Protocol Specification for ensuring Interoperability of High Rate Data Link Stations on the International Space Program
10	SSP 52050	D / 08/06/01		S/W Interface Control Document for ISPR ***ONLY FOR HRDL, SECTION 3.4 ***
11	ECSS-E-40	A / April 1999	13	Software Engineering Standard
12	AMS02-CAT-ICD-R04	29/08/2003	04	AMS02 Command and Telemetry Interface Control document. Section AMS-ACOP Interfaces
13	SSP 52000-PVP-ERP	Sept. 18, 2002	D	Generic Payload Verification Plan EXpedite the PRocessing of Experiments to Space Station (EXPRESS) Rack Payloads
14	NSTS 1700.7B	Rev. B Change Packet 8 / 22.08.00		Safety Policy and Requirements for Payloads using the STS
15	NSTS 1700.7B Addendum	Rev. B Change Packet 1 01.09.00		Safety Policy and Requirements for Payloads using the International Space Station
16	SSP 52005	Dec. 10, 1998		Payload Flight equipment requirements and guidelines for safety critical structures
17	NSTS 18798B	Change Packet 7 10.00		Interpretation of NSTS Payload Safety Requirements
18	MSFC-HDBK-527	15/11/86	E	Materials selection list for space hardware systems Materials selection list data
19	GD-PL-CGS-002	1/ 12-02-99		CADM Plan
20	GD-PL-CGS-004	2/07-04-03		SW Product Assurance Plan
21	GD-PL-CGS-005	2/09-05-03		SW CADM Plan

2.2 REFERENCE DOCUMENTS

RD	Doc. Number	Issue / Date	Rev.	Title
1	GPQ-MAN-02	1		Commercial, Aviation and Military (CAM) Equipment Evaluation Guidelines for ISS Payloads Use
2	BSSC (96)2	1 / May 96		Guide to applying the ESA software engineering standards to small software projects
3	GPQ-MAN-01	2 / Dec. 98		Documentation Standard for ESA Microgravity Projects
4	MS-ESA-RQ-108	1 / 28-Sep-2000		Documentation Requirements For Small And Medium Sized MSM Projects
5	PSS-05			Software Engineering Standards
6	GPQ-010	1 / May 95	A	Product Assurance Requirements for ESA Microgravity Payload. Including CN 01.
7	GPQ-010-PSA-101	1		Safety and Material Requirements for ESA Microgravity Payloads
8	GPQ-010-PSA-102	1		Reliability and Maintainability for ESA Microgravity Facilities (ISSA). Including CN 01

RD	Doc. Number	Issue / Date	Rev.	Title
10	ACP-RP-CGS-003	1/Jan. 05		ACOP Design Report
11	ACP-RP-CGS-004	1/Jan. 05		Electrical Analysis and Design Report
12	ACP-RP-CGS-002	1/Jan. 05		Operational Analysis Report
13	ACP-RP-CGS-005	1/Jan. 05		Structural Analysis and Design Report
14	ACP-RP-CGS-006	1/Jan. 05		Thermal Analysis and Design Report
15	ACP-PL-CGS-002	1/Jan. 05		PA Plan
16	ACP-TN-CGS-002	1/Jan. 05		Flight Safety Data Package 0/1
17	ECSS-Q-60-11A	/ Sept. 2004	A	Derating and end-of-life parameter difts –EEE Components

3. ACOP SYSTEM DESCRIPTION

3.1 INTRODUCTION

The ACOP System is intended to fly on the International Space Station (ISS) as a payload installed into a ISPR on the NASA laboratory. The main objective of ACOP is to provide an ISS Internal Facility capable of supporting AMS-02 experiment, performing the recording of Science data. In particular, ACOP shall allow a more flexible and efficient use of ISS TM downlink, providing a temporary backup of data generated by AMS-02 and preventing, in this way, possible losses of valuable data. In addition, ACOP is the operational interface to on board crew in order to control and monitor AMS-02 inside from ISS and to permit files and SW upload into the supported payloads.
ACOP system shall be installed in the U.S. Laboratory Module, on the ISS, in one EXPRESS rack (see, for reference, Figure 3-1).
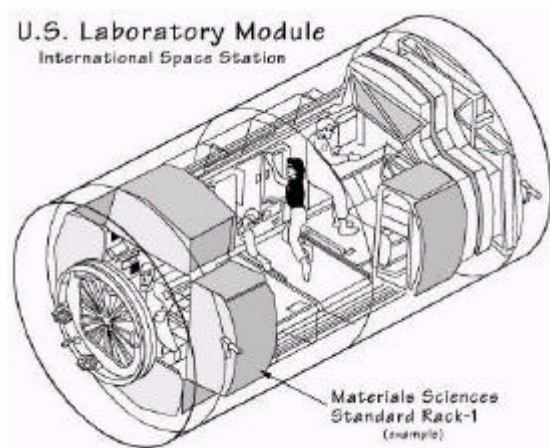

Figure 3-1   US-LAB

The standard configuration of an EXPRESS Rack is commonly known as 8/2. This means that it can accommodate eight ISS locker/Middeck Locker (MDL) and two International Subrack Interface Standard (ISIS), as shown in Figure 3-2. On-Board Spare parts shall be accommodated in a standard soft bag.
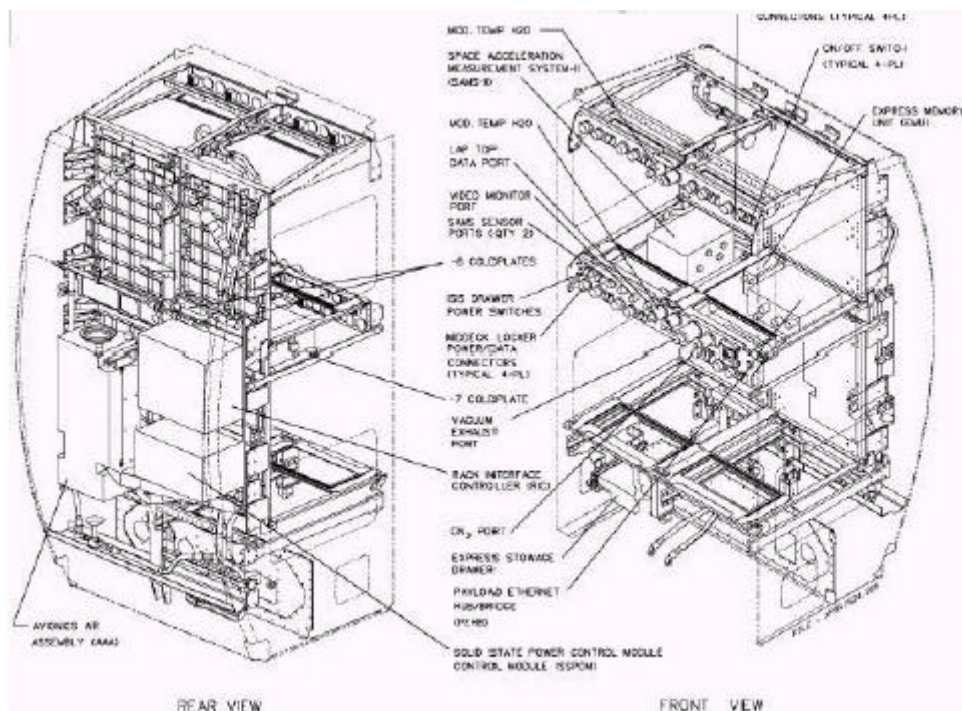
Figure 3-2: Example of Express Rack

3.2   ACOP SYSTEM OVERVIEW

ACOP is reliable special purpose computer to be launched to the International Space Station (ISS) to assist the operations of large science experiment projects. ACOP provides these services:

1. On-orbit recording mechanism for large volumes of data at high rates
2. Play back for downlink of the recorded data at high rates
3. A crew interface for complex experiments
4. General computing facilities
5. Alternate bi-directional commanding path via the HRDL interface

ACOP will initially support a state-of-the-art particle physics detector experiment Alpha Magnetic Spectrometer (AMS-02), which uses the unique environment of space to study the properties and origin of cosmic particles and nuclei including antimatter and dark matter, to study the actual origin of the universe and potentially to discover antimatter stars and galaxies.

After the AMS-02 experiment, ACOP will stay permanently in the US module as the only computer for large science experiment projects on the International Space Station for astronaut crew's use for recording and management of science data, monitoring and control of experiment, as well as improving the data communication between the earth and the space station.

In addition to the ACOP system there will be stowage bag sent to ISS that will contain additional hard drives that can be exchanged with the hard drives in ACOP. From time to time the astronauts will perform this exchange enabling ACOP to record all of AMS-02's data onto fresh hard drives. Once recorded, the data will not be overwritten; rather it will be transported to the ground as a permanent archive (TBC).

3.2.1 FUNCTION AND PURPOSE OF ACOP

ACOP must meet the following requirements of the AMS-02 program:

1. Operate effectively in the ISS space environment.
2. Create an on-orbit recording of all AMS-02 science data on removable[1] media - explicitly hard drives, preferably SATA based.
3. Provide not less than 20 days of recording capacity without crew intervention (based on 2Mbit/second rates), longer would be better.
4. Provide not less than 120 days of recording media capacity within a single mid deck locker equivalent storage unit, longer would be better.
5. Recorded data is an archive. Disks must be provided for the entire 3+ year mission without overwriting (a total of ~23 TByte)[2].
6. For recording ACOP must support an orbital average data rate of not less then 4Mbit/second with bursts of up to 20 Mbit/second.
7. Provide a continuous operations display of ad hoc AMS-02 data for the ISS crew to monitor[3].
8. Provide a continuous means for the ISS crew to issue ad hoc predefined commands without external equipment[4].
9. Provide, as needed, an exhaustive diagnostic, monitoring and operations environment via the EXPRESS laptop computer.
10. Support the playback of recorded data to ground systems at selectable data rates up to at least 20Mbits/second sustained while simultaneously recording at prescribed rates.
11. Support ACOP to AMS-02 commanding at selectable data rates up to at least 20Mbits/second sustained (No requirement for simultaneous recording or playback operations at higher rates.)
12. Support an alternate AMS-02 ground commanding and housekeeping report path via the HRDL interface.
13. CompactPCI based. Preferably 6U form factor.
14. Crew serviceable for upgrades and repairs - hardware and software.
15. Provide for upgrades and expansion to ACOP using COTS subsystems.
16. Provide support of ISS system upgrades (100bt MRDL follow on systems)[5].
17. ACOP will be housed in an EXPRESS Rack Locker.
18. The mass budget for ACOP is 35.5 kg for the EXPRESS Rack Locker and 35.5 kg for the soft stowage bag.
19. The power allocated to ACOP is 200 watts

3.2.2 UTILIZATION CONCEPT

The following are the key points of the ACOP operational concept as it pertains to the AMS-02 mission:

- ACOP is principally a ground operated payload.
- ACOP is powered and active whenever AMS-02 is active. Only short (<8hrs) outages.
- ACOP maintains an active bi-directional connection via the HRDL interface to AMS-02 at all times.
- The AMS-02 TX connection may be tee'd by the APS to the HRFM/KU for direct downlink.
- ACOP provides the mechanism for the crew to monitor and control AMS-02. Both front panel and ERL based interfaces are supported.
- As KU access is available, ACOP will be commanded to use its additional TX connection to down link data. ACOP will have the ability to burst this transmission (~20Mbits/sec).
- All data transmitted by AMS-02 is recorded onto ACOP's hard drives as a master copy of the AMS-02 science data.
- When ACOP has acknowledged that the data is recorded, AMS-02 can release that data from its buffers.
- The four hard drives installed in ACOP provide an estimated 20 days of recording (Note: Dependent on event

---

[1] Hot swap software not required but performing a hardware hot swap must not permanently damage the system

[2] The current contract ASI N. I/044/04/0 foresees the provision of 14 nominal hard drives plus 2 hard drives as spare parts. The individual hard disk capacity is 200 – 250 GB (TBC).

[3] The design presented in this report foresees the presence of a LCD monitor, not foreseen in the contract ASI N. I/044/04/0

[4] The design presented in this report foresees the presence of a LCD monitor, not foreseen in the contract ASI N. I/044/04/0

[5] Not foreseen in the contract ASI N. I/044/04/0

rate and size.)

- The four installed hard drives will require periodic replacement by the ISS crew from the onboard stock of empty drives (30 minute operation about every 20 days)
- A batch of 20 hard drives provides 150 days of recording capacity.
- New batches of hard drives will be delivered by STS and the original master copies of the AMS-02 data will be returned to earth by STS.

3.3 MECHANICAL STRUCTURE

ACOP is installed in the location of MDL of EXPRESS Rack as shown in the following figure and should blind mate with the back plate of the rack.
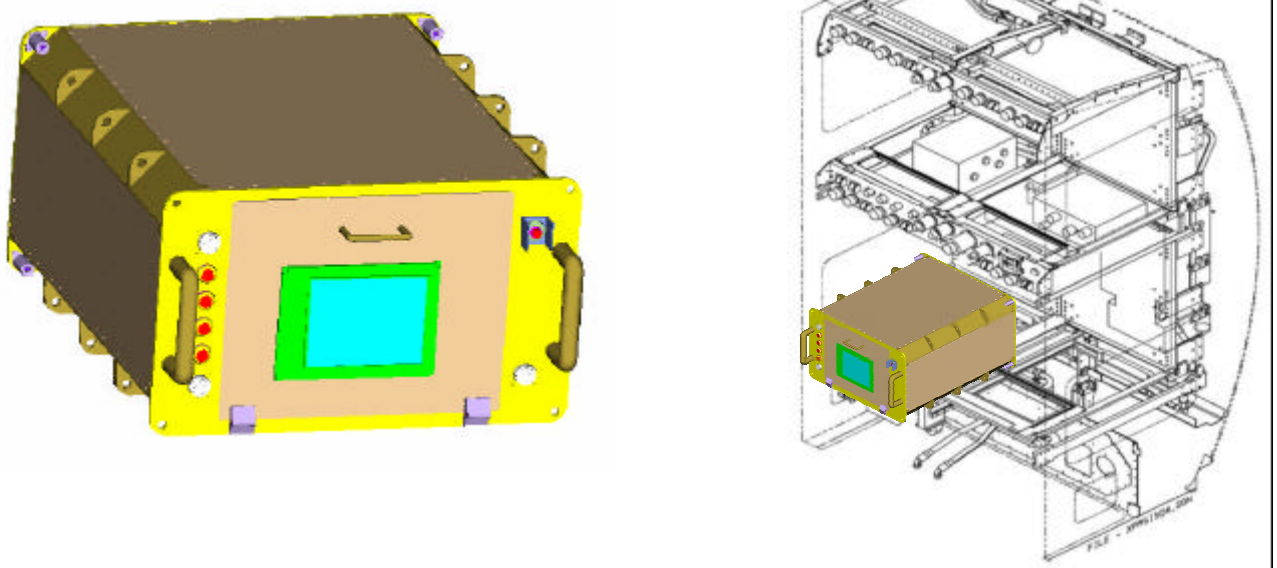
Figure 3-3 Location and configuration of ACOP

Mechanical structure of ACOP is mainly constructed by an outer structure (LOCKER) and an inner structure (CHASSIS The locker will be mounted to the back-plate of the EXPRESS Rack and the chassis will support the electrical components..
The main mechanical parts of ACOP are listed below:

Item	Function	Quantity	Note
LOCKER	Outer structure (shell) of ACOP. Structure interface to back plate of RACK	1 set	Assembly of 6 plates and 4 beams, Integrated by flat head #4 screws
FRONT PANEL (Fixed)	Part of LOCKER Supporter of all IO connectors	1 piece	
FRONT PANEL (Opening)	Access for HARD DRIVE replacement Location of LCD (TBC)	1 piece	Opened with friction hinge, closed by 1/4 Turn fasteners
CHASSIS	Inner structure of ACOP Supporter of electric components Fins for heat dissipation	1 piece	Produced by wire cutting, all in one piece. It will be fixed to the locker by means of flat head screws size # 6 or #8 (TBC).
SIDE PLATE	Enclose airflow inside the fin channel Prevent occurrence of turbulence in front space.	2 pieces	Fixed with CHASSIS by #4 flat head screws

Item	Function	Quantity	Note
BP FRAME	Frame for Back Plane Resist the force when connector plug in	1 piece	Integrated with Back Plane by screws
DUCT	Air duct for air inlet and outlet Airflow channels between CHASSIS and LOCKER	2 sets	Made from metal plate, integrated with CHASSIS and LOCKER by #4 flat head screws
CADDY	Frame for HD Heat sink and path of HD	4 pieces	
AIR FILTER	Filter for airflow	2 pieces	Mounted from outside of LOCKER back plate

Table 3-1 Main Mechanical Parts
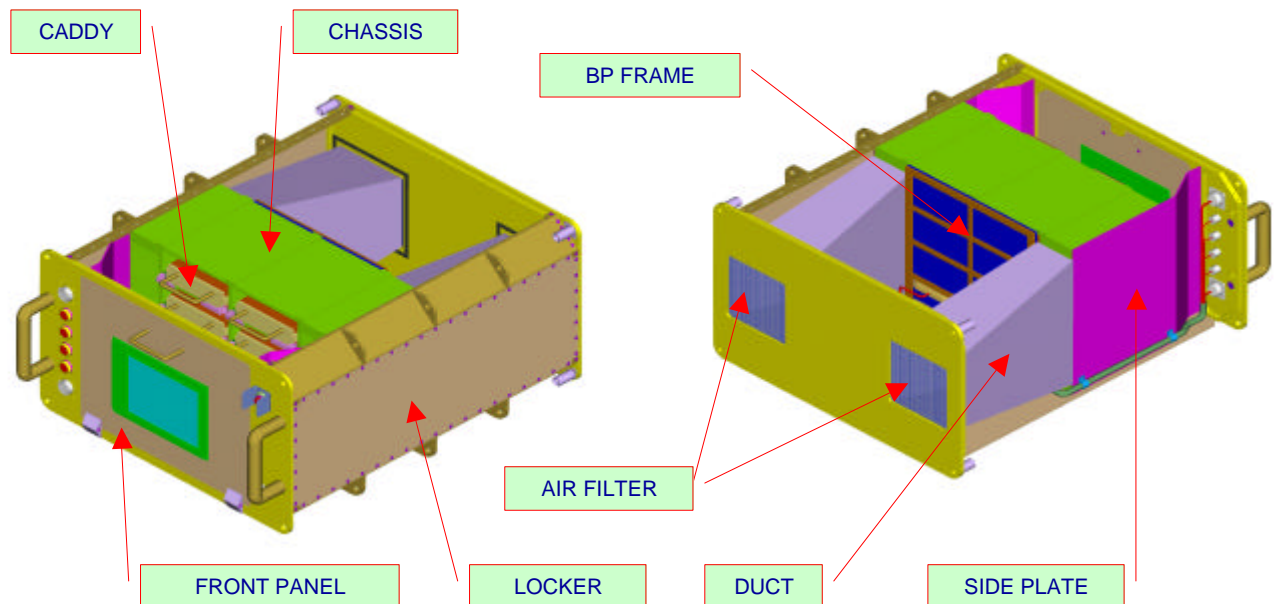
Figure 3-4 Mechanical Main parts of ACOP

There are 4 HARD DRIVEs installed in the upper part of the Chassis and 5 PCI with 1 power supply installed in the lower part of the Chassis as shown in the Figure 3-5.

PCI

HARD DRIVE   LCD   POWER SUPPLY   BACK PLANE   CABLE
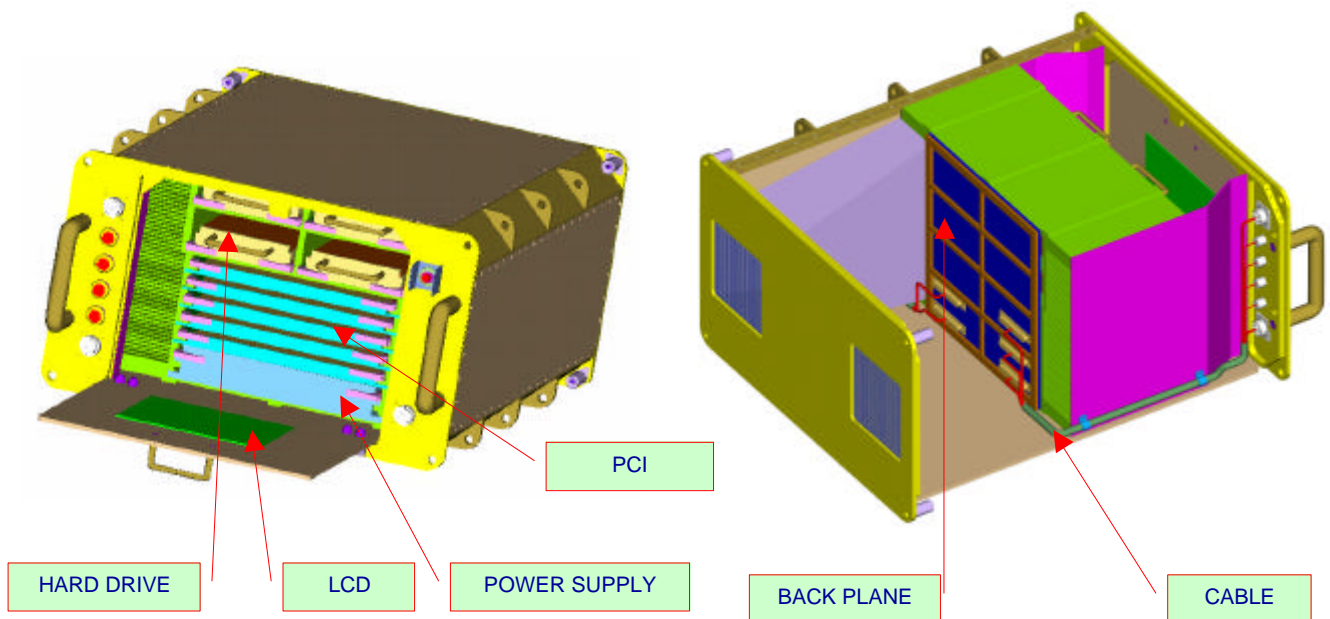
Figure 3-5 Electric Main parts of ACOP

At moment the hard drives are under selection so the final choice is TBC. All CompactPCI, Hard Drives, and the Power Supply are fixed and extracted by hand operated card locks as shown in the Figure 3-6. No special tools are required.

HD Extraction

PCI Extraction

Figure 3-6 Card Locks

The most important matters concerned for hard drive installation and replacement are reliability and human factor. The connectors will be put on the rear side of the CADDY of the Hard Drive and plugged into the corresponding connector on the Backplane.as shown in the Figure 3-7. The force to plug in or out the connector is tested to be 5 kg for a 26 pin D-Sub type connector .
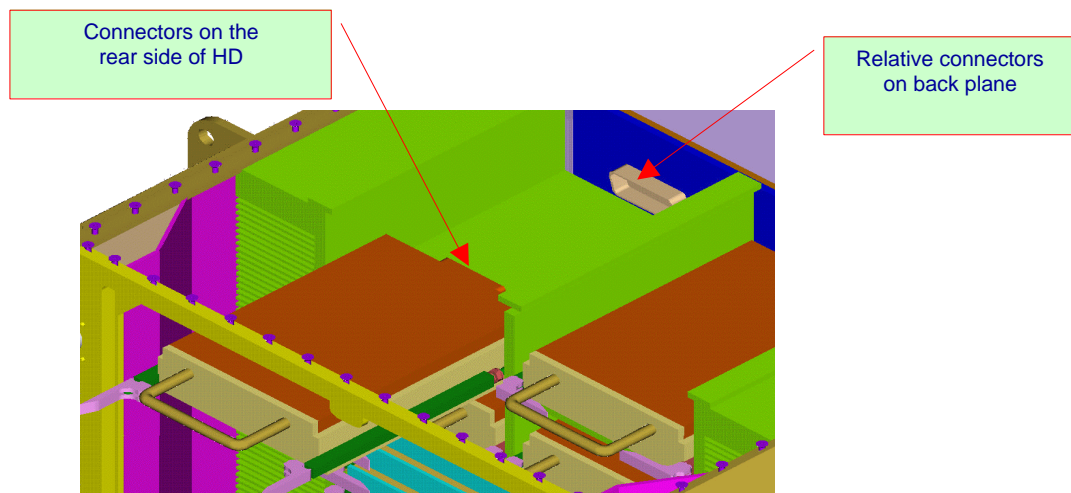
Figure 3-7 HARD DRIVE installation

All external connectors, push buttons, circuit breaker, and LCD (TBC) are mounted on the Front Panel as shown in the Figure 3-8.
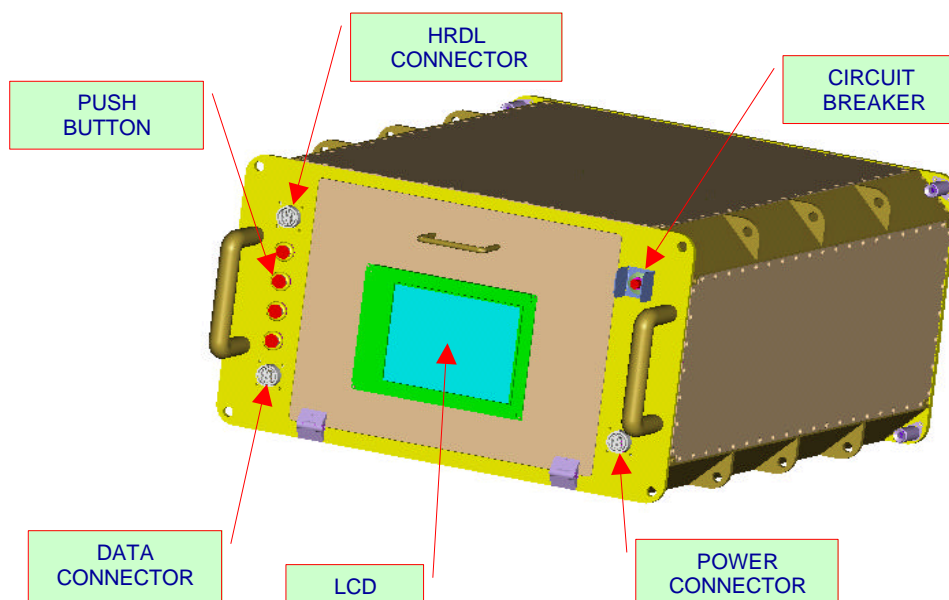
Figure 3-8 Layout on Front Panel

Main front Panel shall be mounted with LCD Panel (TBC) and can be opened with friction hinge. It is locked by four 1/4 fasteners and one magnetic latch.
LCD display is covered by plastic covering to avoid potential shatterable material hazard.

Following components are mounted in the Front Panel:

- Four Momentary Press Buttons
- One Circuit Breaker On/Off Switch
- One HRDL Connector
- One Power Connector
- One MRDL Connector

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3.3.1 CABLE HARNESS

Cable that come from the Back Plane will pass through the space between CHASSIS and LOCKER on both sides and go to the Front Panel.
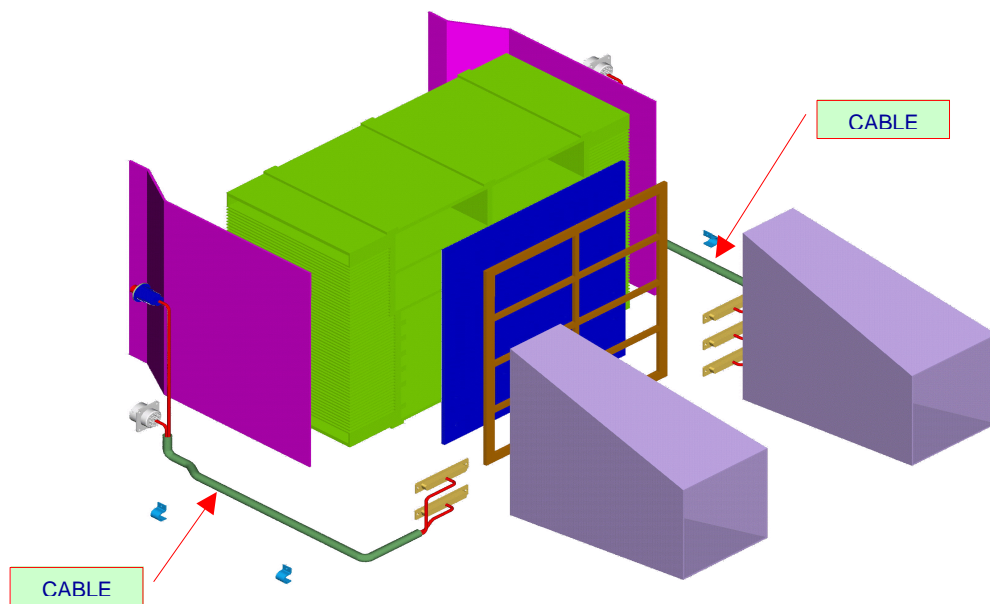
Figure 3-9 Layout of cable (rear view)
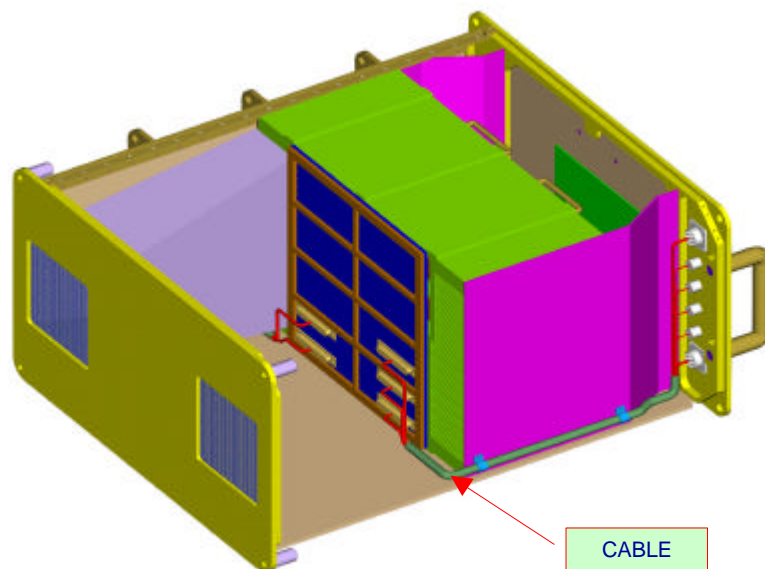
Figure 3-10 Layout of cable (side view)

3.4 ELECTRICAL

3.4.1 ISS AVIONICS ARCHITECTURE

The ISS Command & Data Handling (C&DH) of the ACOP and AMS-02 system is shown as Figure 3-11.
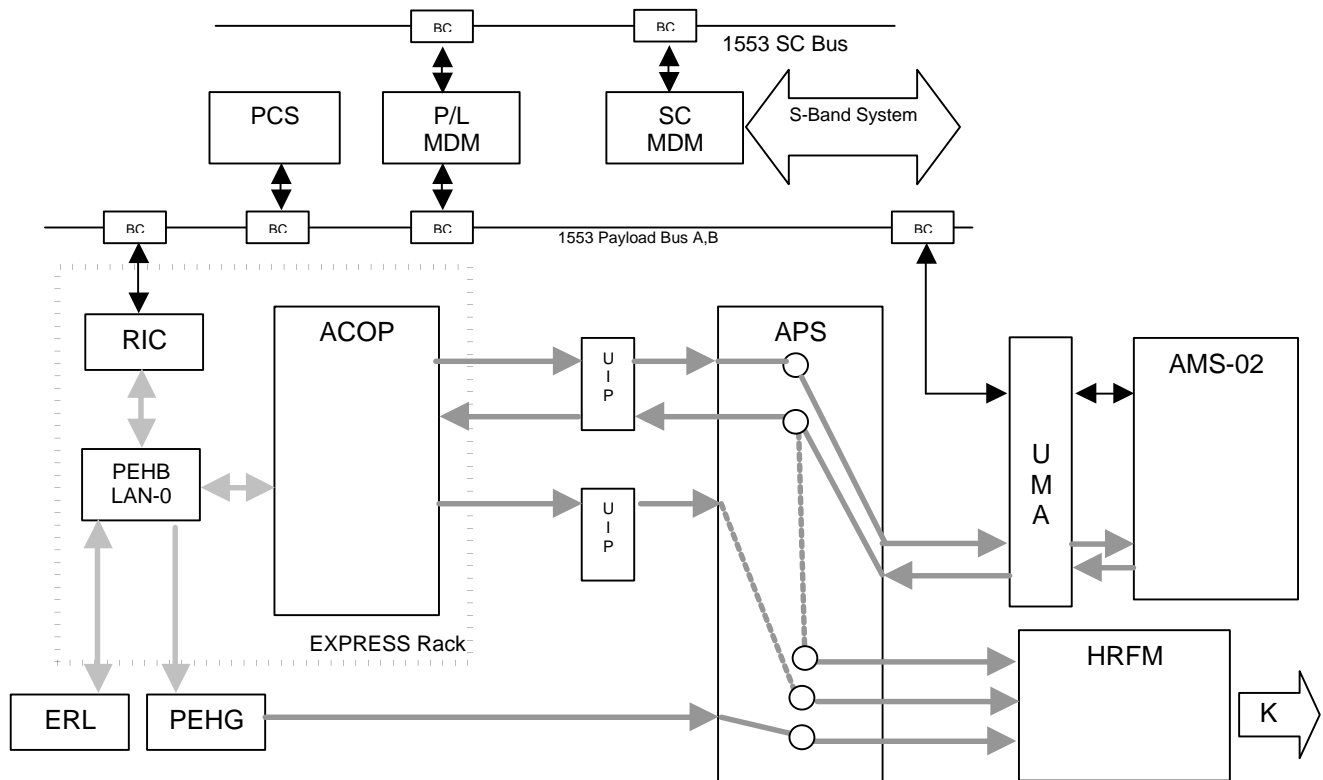
Figure 3-11 AMS-02 Avionic Architecture

Commanding and housekeeping data for ACOP is handled via the EXPRESS Rack Interface Controller (RIC). ACOP communicates with the RIC software on an Ethernet connection via the Payload Ethernet Hub Bridge (PEHB) using the Transmission Control Protocol/Internet Protocol (TCP/IP).

All ISS HRDL fibers are connected to the Automated Payload Switch (APS). This device provides cross bar switching among the fiber systems of ISS. ACOP has two prime targets for HRDL transfers. The first is the High Rate Frame Multiplexer (HRFM - via the High-Rate Communications Outage Recorder (HCOR). The HRFM interleaves data to the KU-Band transmission system for downlink. The second target is the AMS-02 payload. The APS can be configured to tee data transmitted by AMS-02 to both the HRFM and ACOP.

ACOP maintains an active bi-directional connection via the HRDL interface to AMS-02 at all times. As KU access is available, ACOP will be commanded to use its' additional TX connection to down link data. ACOP will have the ability to burst this transmission (~20Mbits/sec). All data transmitted by AMS-02 is recorded onto ACOP's hard drives as a master copy of the AMS-02 science data. When ACOP has acknowledged that the data is recorded, AMS-02 can release that data from its buffers.

3.4.2 ACOP AVIONICS ARCHITECTURE

The ACOP system is based on CompactPCI systems. It contains a single board computer and several custom developed interface boards (including HRDL fiber interface, Ethernet interfaces, two USB interface to upgrade the operating system and programs, and digital input-output and video interface). ACOP will also contain four

exchangeable hard disks used to archive the data and the necessary interfaces. Other parts of ACOP are a flight qualified LCD (TBC) screen and a simple push button interface, connected via peripheral cards.

In the main chassis and front panel are the electrical parts which include a set of digital computer hardware and software, the functional block diagram of electrical parts is shown as Figure 3-12.
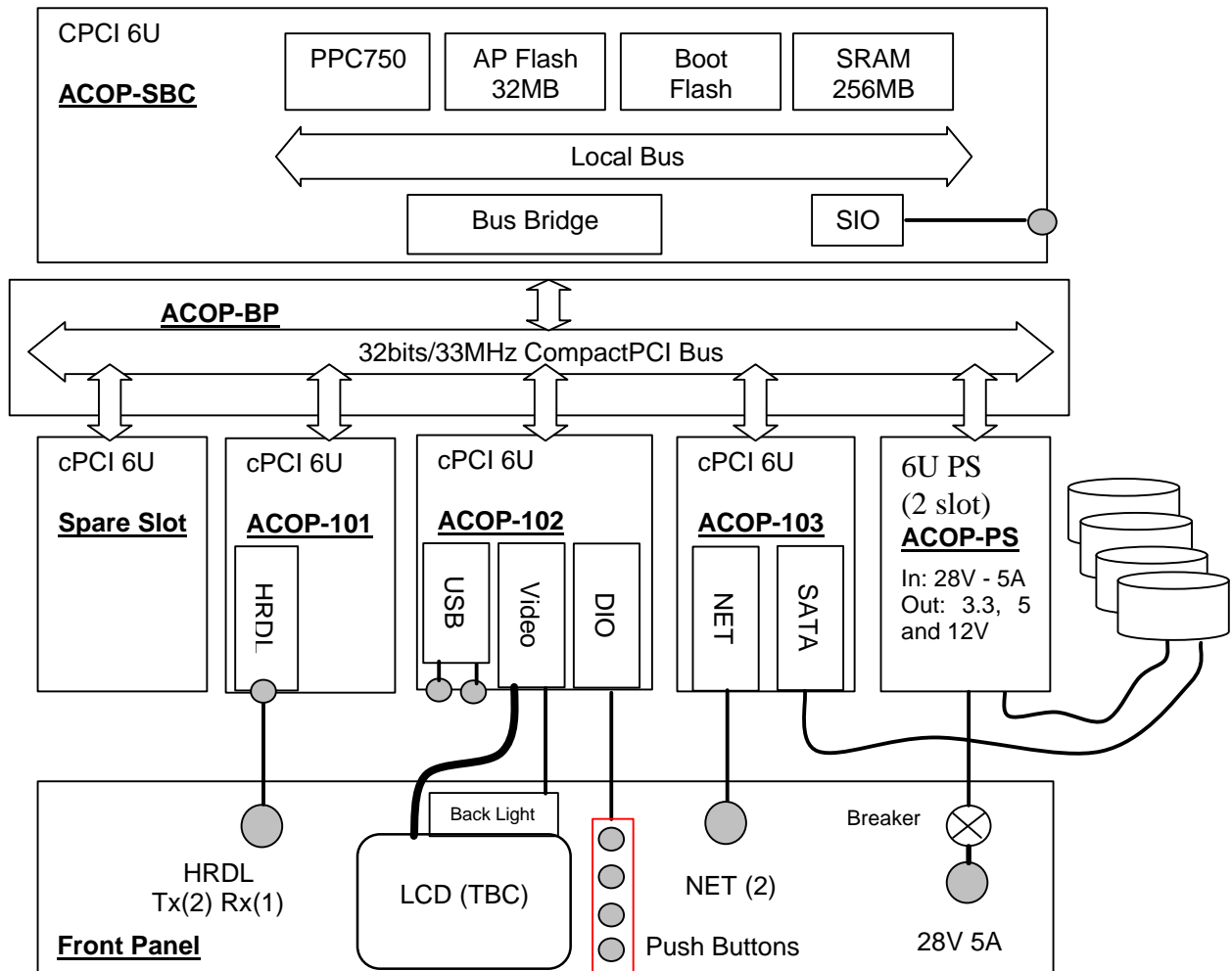
Figure 3-12 ACOP Electrical Block Diagram

The ACOP chassis includes the following modules:

- ACOP-SBC: Single board computer, based on the IBM PPC 750, which provides 400Mhz speed as well as standard CompactPCI bus interfaces and acts as CompactPCI system slot.
- ACOP-T101: Provides 2 fiber optic TX and 1 fiber optic RX interfaces.
- ACOP-T102: Provides video output interface (TBC), 2 USB 1.1 interfaces and a DIO interface.
- ACOP-T103: Provides 2 Ethernet ports and 4 SATA ports.
- Spare Slot: for future expansion purpose
- ACOP-PS: Double height power supply.
- 4 hot swappable HDD (Hard Disk Drive)

The ACOP front panel will be mounted with:

- Four Momentary Press Buttons
- One Circuit Breaker On/Off Switch
- One HRDL Connector
- One Power Connector
- One MRDL Connector with 10/100 base Ethernet
- One LCD screen with backlight (TBC)

During the engineering development stage, the I/O configuration will be tailored with PMC mezzanine modules and all modules integrate in an industry standard CompactPCI backplane. The design is scaleable and expandable, with a clear and built-in path for technology upgrades and insertion. A well-defined avionics Application Programming Architecture abstracts the application software from the underlying hardware, affording system evolution to ever-increasing performance standards, while effectively managing obsolescence. The Ethernet interface and USB interface can also supports software development and system maintenance during development.

3.4.2.1 POWER DISTRIBUTION AND POWER FEEDERS PROTECTIONS

ACOP is supplied by the +28Vdc standard power feeder provided by the EXPRESS Rack. A circuit breaker with a switch mounted on the front panel provides the On/Off switching capability. When the switch is moved to the on position power is provided to the system. During power stabilization the ACOP single board computer CPU is held in reset; once power is stable reset is released and the system begins the boot phase.

The circuit breaker is used also to protect wirings and downstream circuits from thermal damage that occurs during an over-current situation and as the first step of defense against electrical hazards. Circuit breaker's features include fail-safe operation, ambient temperature compensation and load protection function.

The circuit breaker's output supplies the ACOP Power Distribution module (ACOP-PS), which is based on power DC/DC converter implemented with hybrid integrated circuits. Each one incorporates two filters designed with output common mode filter chokes and low ESR capacitors, as shown in Figure 3-13.
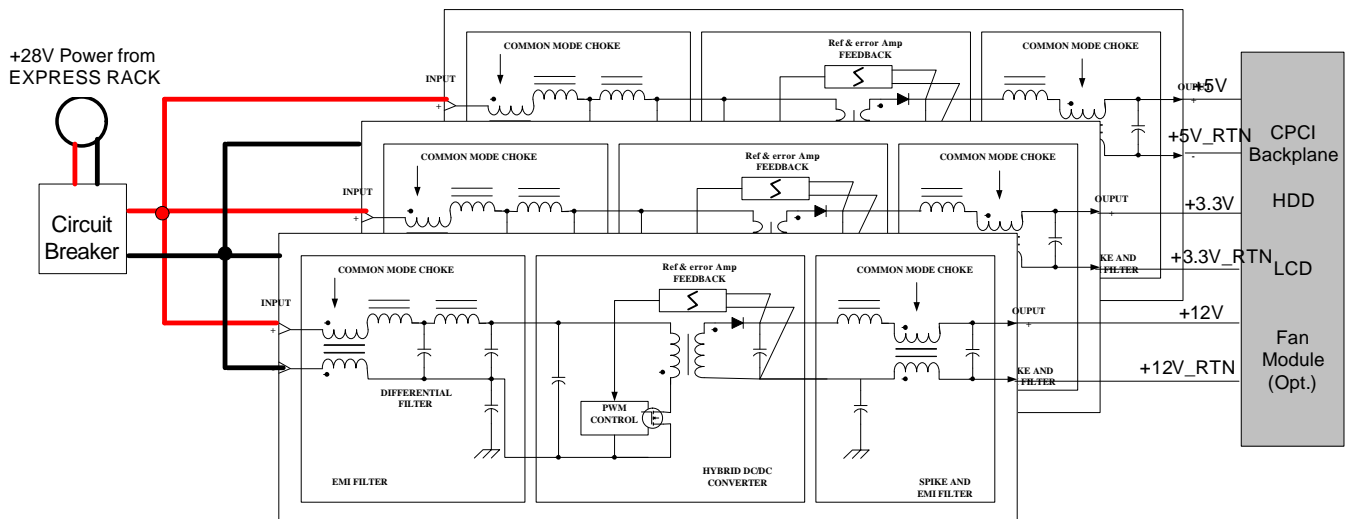
Figure 3-13 ACOP Power Distribution Diagram

On the power input side of the ACOP-PS, for each DC/DC converter the common mode currents are interrupted by a high inductance common mode choke. A shunt capacitor connected to the hybrid integrated circuit case allows the common mode input currents to be localized, instead of flowing out to the input leads.
Two stages of LC differential filtering are used to reduce ripple current levels. By using two cascaded higher frequency stages, each stage is physically smaller than a larger, lower frequency single stage.

On the output side of the ACOP-PS, for each DC/DC converter a common mode choke and a shunt capacitor to the hybrid integrated circuit case completely tame the common mode spikes. A small differential filter adds the final bit of filtering to the output leads. At above approximately 10 MHz, the output filters within the hybrid can become capacitive: external ferrite leads and small capacitors may be used to tame the residual high frequency spikes.

Three different voltages, 3.3V, 5V and 12V, are distributed from ACOP–PS to CompactPCI backplane and other stand-alone devices. The ACOP-SBC board will provide a power monitor circuit for both the 3.3V and 5V supplies: during power up, the 3.3V power monitor circuit will hold the ACOP in reset until the power is stable. The 5V power monitor signal will be latched when activated and the latched results will be provided as input to the CPU for software reading.

3.4.3 AVIONICS DESIGN DETAIL

The mechanical design of ACOP card cage assembly is shown as Figure 3-14.
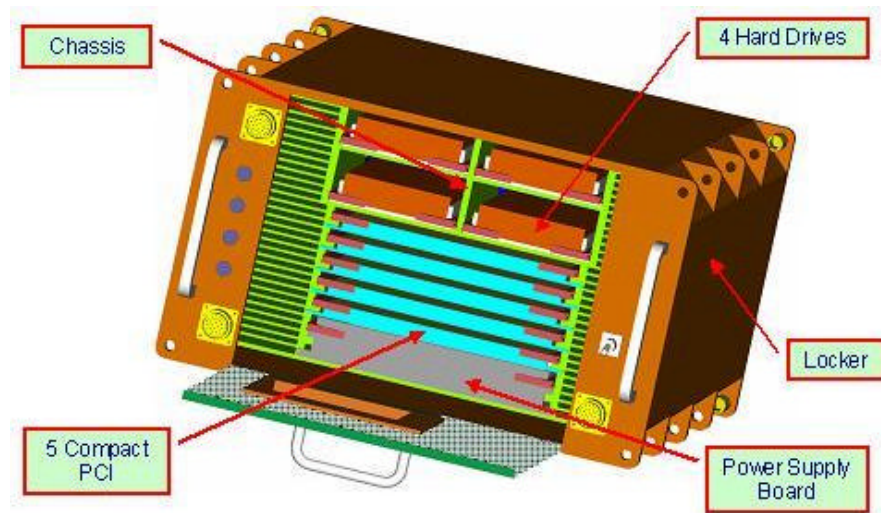
Figure 3-14 ACOP Main Components

The main characteristics of the ACOP card cage assembly are:

- 6U card cage for 5 double Eurocard CompactPCI boards in a CompactPCI chassis.
- Conduction cooling and wedge-locks for CompactPCI boards and power supply board.
- Double height power supply slot.
- Mounting provisions for CompactPCI backplane.
- 4 hard drives with caddies that can be removed from the chassis

The CompactPCI bus combines the performance advantages of the PCI desktop architecture with the ruggedness of the Eurocard form factor, a widely used standard within the industry for over 20 years. The Eurocard boards provides more secure connectors and more available space for professional embedded platforms than the PCI cards in desktop computers. The CompactPCI standard has widely been accepted for a large spectrum of applications.

In ACOP card design is based on the "IEEE 1101.2- Mechanical Core Specification for Conduction Cooled Eurocards" specification and the board layout is shown in Figure 3-15:
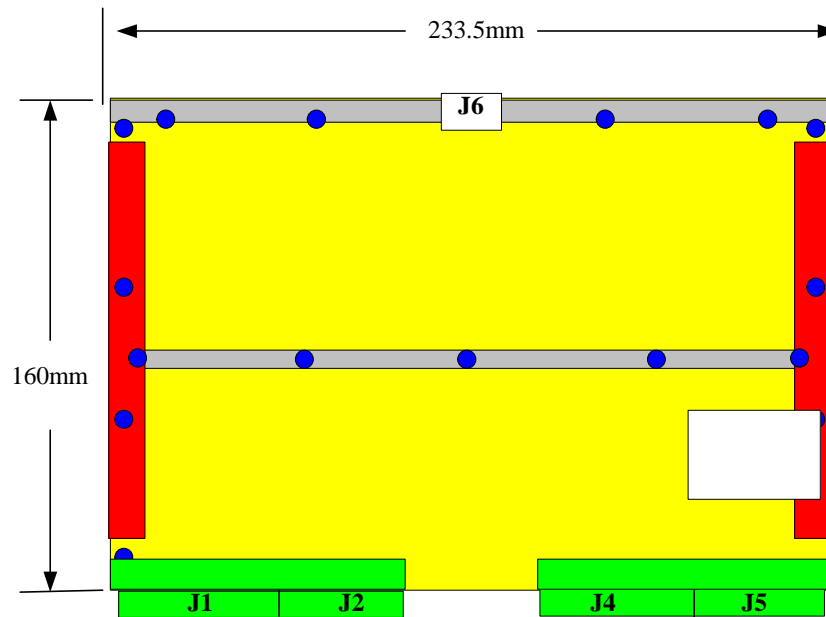
Figure 3-15 IEEE 1101.2- Mechanical Core Specification for Conduction Cooled Euro cards

To allow the ACOP to operate in the ISS, the circuit card design incorporate the following techniques:

- Buried thermal layers within the PCB
- Heat sink for high power components
- Stiffening ribs cross the board
- Expandable wedge lock on both sides

3.4.3.1 ACOP-SBC

The ACOP-SBC is a single slot 6U CompactPCI form-factor board that fits into a system slot of a standard CompactPCI backplane. It consists of an IBM PowerPC750 CPU with system memory, several peripherals and the CompactPCI interface. Figure 3-16 shows the main functional blocks that make up the ACOP-SBC board. There are two bus sections in the ACOP-SBC board design: the CPU bus provides connections to the North PCI Bus Bridge chip, which provides the connections to the processor memory.
The processor memory includes read only boot PROM, FLASH memory and SDRAM. The system allows the operational memory configuration to be customized to the specific application.
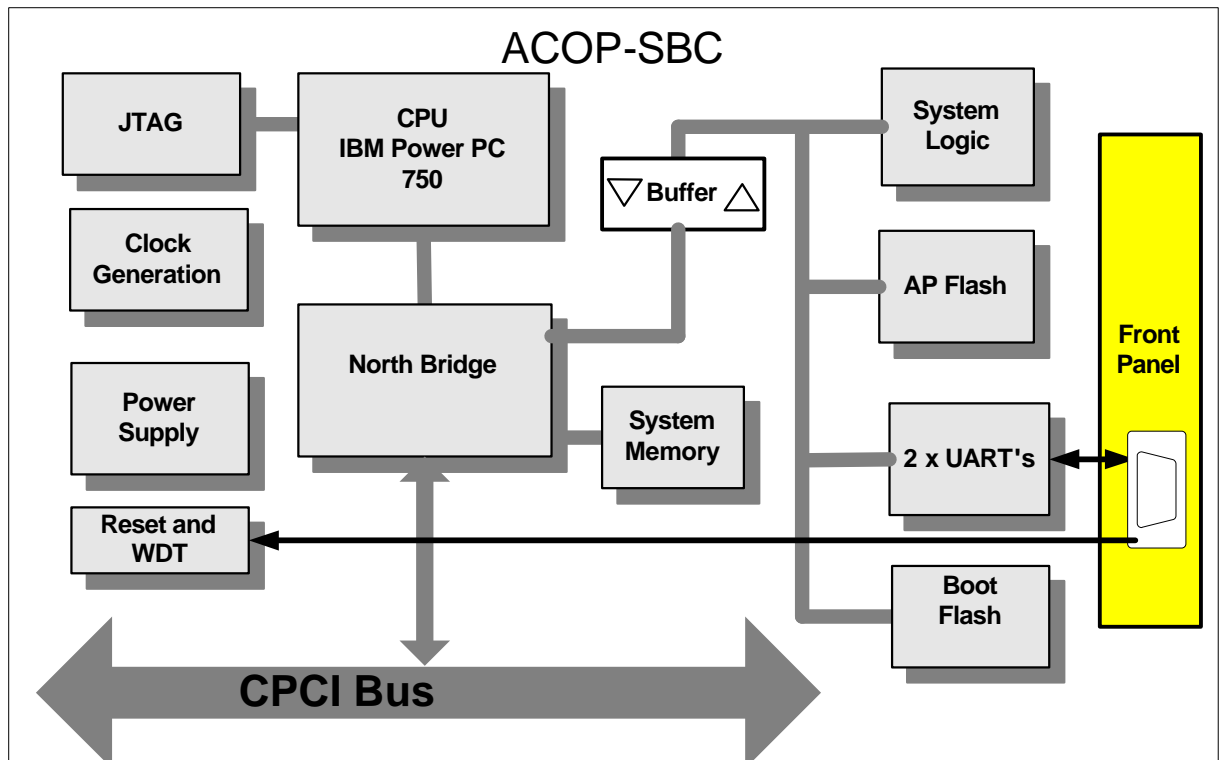
Figure 3-16 ACOP-SBC Functional Block Diagram

The following is a list of the hardware features for the ACOP-SBC:

- Microprocessor:
    - o IBM PowerPC750 running at 400 MHz, On-chip Cache (I/D): 32K/32K
- CPU to PCI Bridge:
    - o The CompactPCI backplane bus is 33MHz / 32-bit PCI
    - o Up to 75MHz CPU bus frequency
    - o CPU to SDRAM bridge
    - o CPU to PCI bridge
    - o PCI to DRAM bridge
    - o Compatible to PCI rev 2.1
- Main Memory:
    - o Synchronous Dynamic RAM (66MHz)
    - o 64 bit DRAM data path interface
    - o 256Mbyte Synchronous DRAM supported
- On-board Flash Memory:
    - o 32 bit Flash data path
    - o 4Mbyte (1M x 32) standard configuration
    - o 8Mbyte (2M x 32) optional configuration
- One 32 Pin JEDEC standard EPROM PLCC socket:
    - o 8-bit EPROM data path interface
    - o Up to 512KB EPROM supported
- Dual serial interface ports:
    - o 16552D (16550A compatible)
    - o RS422 Interface
- General Purpose Registers
- Reset Generation

- Thermal sensor input
- 32bits /33Mhz CompactPCI system slot, PICMG 2.0 compliant

3.4.3.2 ACOP-T101

The ACOP-T101 module provides two transmit and one receive fiber optic interfaces meeting the ISS HRDL CCSDS packet mode standards. The hardware structure of ACOP-T101 board is shown in Figure 3-17. Two ZBT SRAM chips are used as buffer between System slot and the FPGA chip. The PCI agent chip (Actel A54SX72A) includes two main functions:

1) translator between the PCI bus and interface back-end bus
2) handling of the read/write operations (PCI memory space access) on the left port of the DPM buffer

The FPGA chip accesses the DPM buffer though its right port. It also has a 5 bit parallel data interface with physical data transmitter (AM79865) and receiver (AM79866A) for HRDL.

Figure 3-17 ACOP-T101 Functional Block Diagram

The following is a list of the hardware features for the ACOP-T101:

- Include two transmit and one receive fiber optic interfaces meeting the ISS HRDL CCSDS packet mode standards
- The interface provides intelligent reception and transmission of variable length CCSDS packets referred to as frames
- Ram data is received into and transmitted out of a buffer memory of 1MB contained on board. The configuration of FIFOs to manage the data is done by software allowing support for varying operational modes.
- Software configurable sync-symbol insertion parsing in terms of a data-symbol to sync-symbol ratio as well as specifying the number of sync-symbols between frames.
- The interface removes all sync-symbols on reception.
- The interface provides a means to transmit test patterns of symbols, including both valid and invalid symbols
- Transmitter capable to transmit frame from 1 to 4096 bytes length
- Data symbols can be interleaved with sync symbols d:s where d=0:20 s=0:20 where d is the number of consecutive data symbols and s is the number of consecutive sync symbols. Either s or d being zero means no syncs are inserted

- The number of sync symbols in the gap between frames can be specified between 1 and 2 ** 23 –1 inclusively
- Receiver can receive frames from 0 to 4096 symbols with all sync symbols removed.
- 32bits /33Mhz CompactPCI peripheral slot, PICMG 2.0 compliant

3.4.3.3 ACOP-T102

The block diagram in Figure 3-18 shows the major systems that make up the ACOP-T102 board. An ACTEL A54SX72A FPGA is used to implement the PCI agent and VGA controller function. It is compliant with the PCI 2.2 specification and provides 33MHz performance. Two ZBT SRAM chips are used as video memory and buffer between system slot and the FPGA chip.
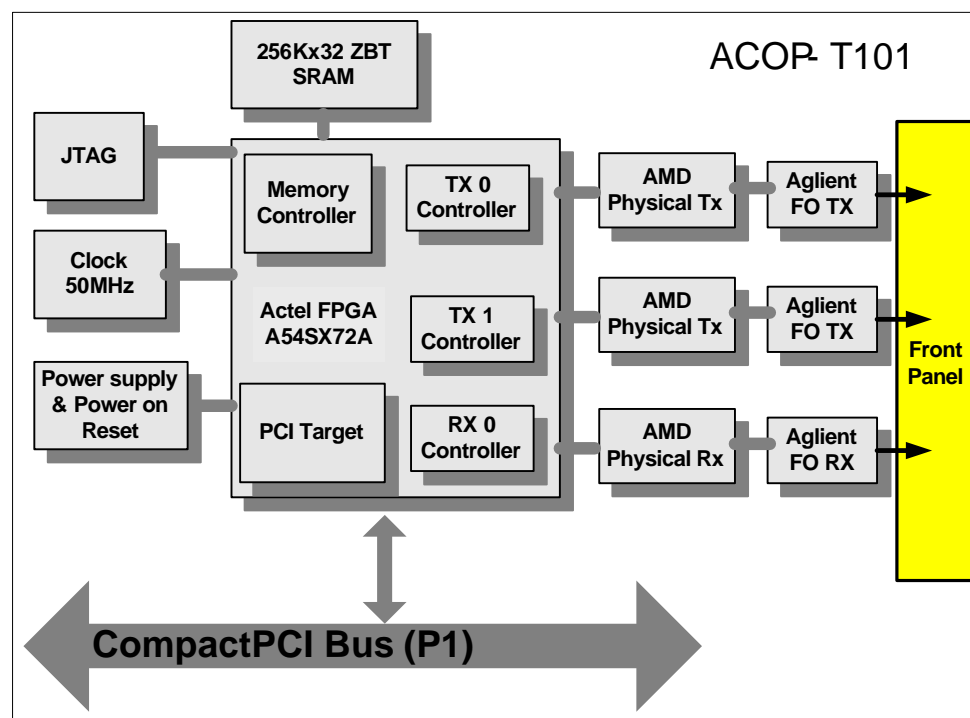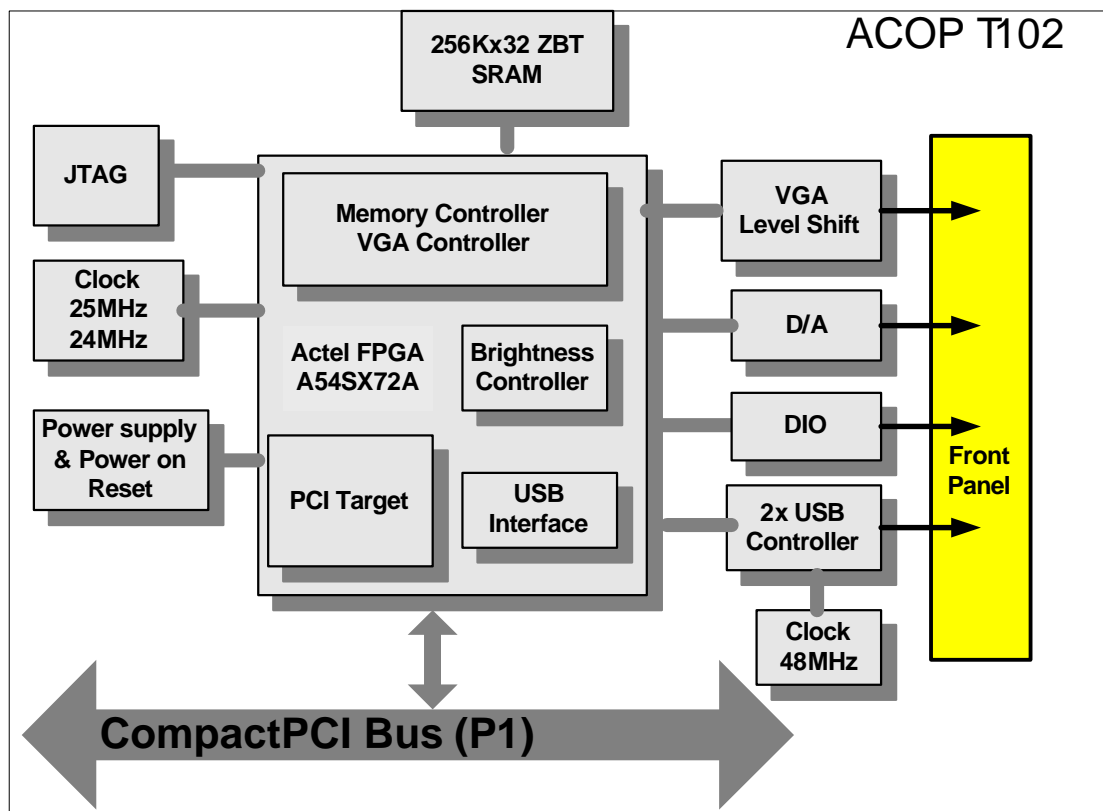

Figure 3-18 ACOP-T102 Functional Block Diagram

The following is a list of the hardware features for the ACOP-T102:

- LCD Graphic Function (TBC):
    - o Only graphic mode supported.
    - o Resolutions: 640x480 and 320x240
    - o Color: 5 bits (bit1 to bit 5) for R, G, B. The value of bit 0 of each color is fixed to zero.
    - o Clock frequency: 25MHz
    - o Vertical frequency: ~ 60Hz
    - o Video SRAM: 256K x 32bit

- D/A converter with analog output to adjust the brightness of the LCD backlight (TBC)

- USB interface:
    - o Supports USB Specification 1.1 (1.5Mb/s) devices
    - o Allow one PCI transaction to access both SL811HS controllers.

> o Support burst R/W by using backend throttling

- 32bits /33Mhz CompactPCI peripheral slot, PICMG 2.0 compliant

3.4.3.4 ACOP-T103

The ACOP-T103 provides four (4) separate SATA channels to access storage media such as hard disk drive. It uses a PCI-to-Quad-SATA Controller that supports a 32-bit, 66 or 33MHz PCI bus. It accepts host commands through the PCI bus, processes them and transfers data between the host and Serial ATA devices.
It can be used to control four independent Serial ATA channels: each channel has its own Serial ATA bus and will support one Serial ATA device with a transfer rate of 1.5 Gbits/sec (150 MBytes/sec).

The ACOP-T103 also provides two independent high-performance Fast Ethernet interface controller ports.
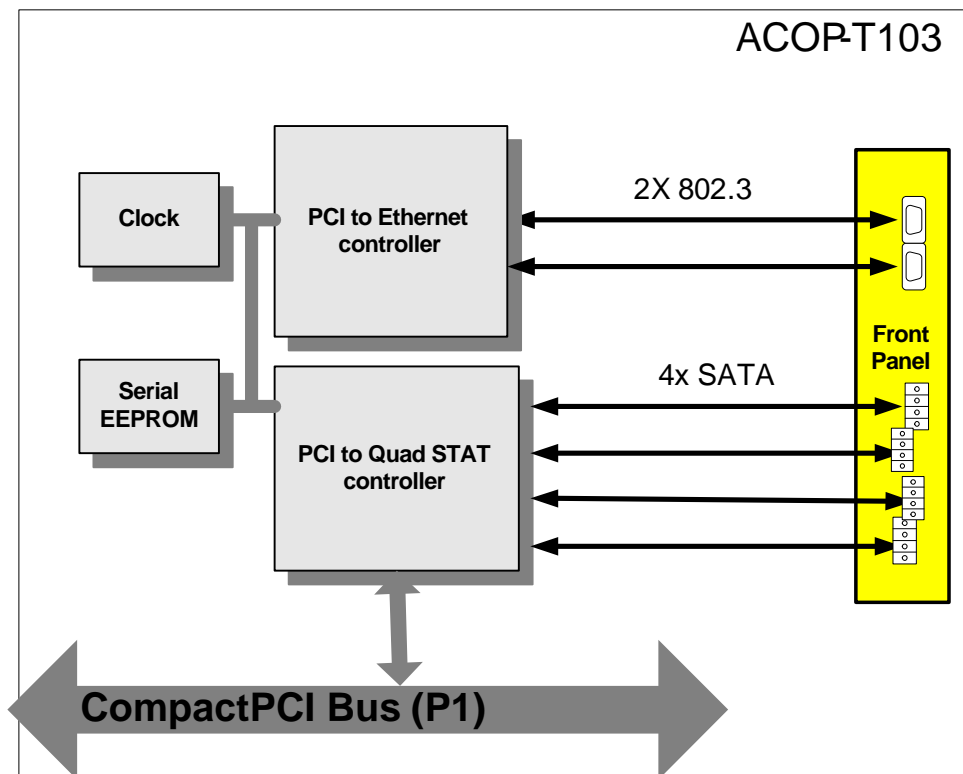
Figure 3-19 ACOP-T103 Functional Block Diagram

The following is a list of the hardware features for the ACOP-T103:

- PCI to 4-port Serial ATA (SATA) host controller
- Serial ATA transfer rate of 1.5Gbit/second
- Spread spectrum receiver and single PLL for all channels
- Independent 256 byte (32-bit by 64) FIFO per channel
- Integrated Serial ATA Link and PHY logic
- Compliant with Serial ATA 1.0 specifications
- Two IEEE802.3 10/100Base Ethernet ports, Both TX and RX supported
- 32bits /33Mhz CompactPCI peripheral slot, PICMG 2.0 compliant

3.4.3.5 ACOP-BP

The ACOP-BP backplane is compliant to the PICMG 2.0 R3.0 standard for backplane, module connectors, mechanical and power interfaces. CompactPCI signals are routed on P1 connector row only. P2 connectors are installed only on the system slot positions. P3 connector row is not used at all.

Each of the CompactPCI segments provides +3.3 VDC signal environment only. All V(I/O) pins of each slot are connected to the corresponding +3.3V power planes. The peripheral interface signals for ACOP specific applications are routed on P4.
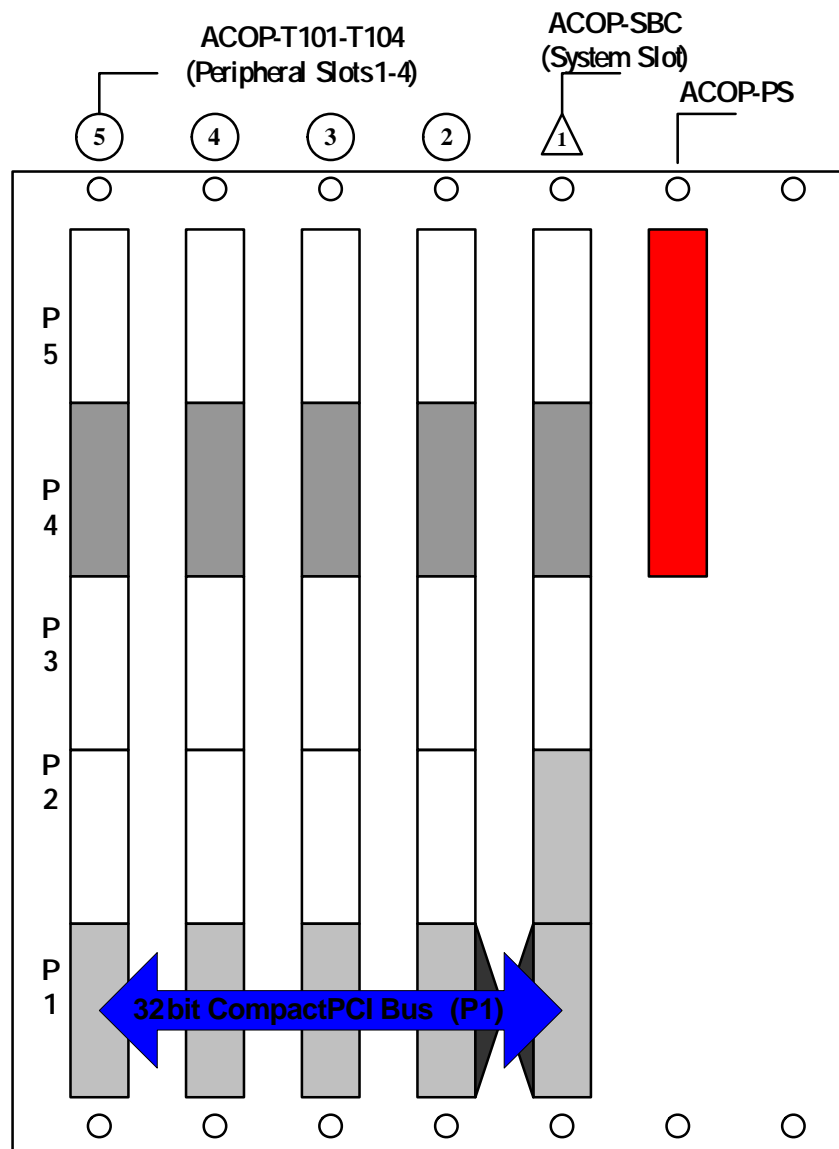
Figure 3-20 ACOP-BP Functional Block Diagram

The following is a list of the hardware features for the ACOP-BP:

- Compliant with the CompactPCI core specification (PICMG 2.0 R3.0), including the external +12V and -12V power lines connectors for ground test only.
- support 32-bit, 33 MHz PCI bus operation
- 3.3V V(I/O) signaling voltage only

- no Hot Swap capability, no Rear I/O capability
- 5-slot wide, one system and four I/O slots
- Standard 47 pins power supply slot
- Position of the AMS-02 specific I/O modules is predefined.

3.4.3.6 ACOP-PS

The ACOP-PS module is CompactPCI form factor and installed in the backplane. The input voltage range is 24 to 32Vdc, compliant with the +28Vdc power feeder voltage range provided by the EXPRESS Rack.

Three outputs (generated by power DC/DC converter implemented with hybrid integrated circuits) provide 3.3Vdc, 5Vdc and 12Vdc power supplies with independent output regulation. The outputs of the ACOP-PS meet the electrical requirements of PICMG specification for CompactPCI systems.
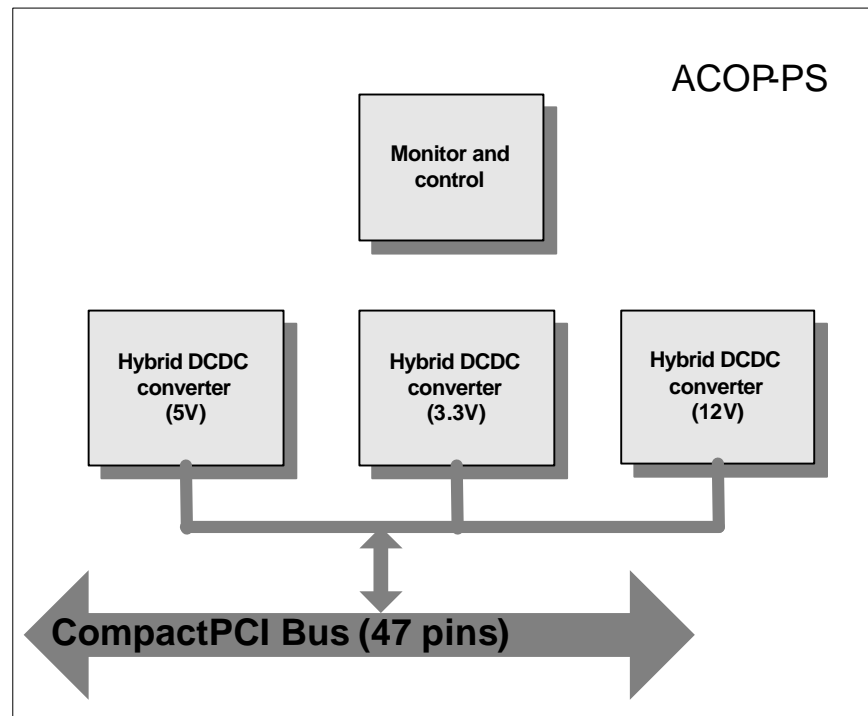
Figure 3-21 ACOP-PS Functional Block Diagram

The following is a list of the hardware features for the ACOP-PS:

- Inrush Current: TBD A peak @ TBD VDC
- Efficiency: > 75% @ full load, nominal line
- Output Power: TBD watts
  +5.06V +/-3% : TBD A
  +3.36V +/-3% : TBD A
  +12.1V +/-5% : TBD A
- Protection : Over voltage, over current, short circuit, over temperature and fault isolation
- Built-in EMI filter
- Backplane power connection via PICMG 2.11 compliant 47-pin power connecter.

3.4.3.7   LCD (TBC) PANEL MONITOR

A Color Active Matrix Liquid Crystal Display (LCD) with an integral Cold Cathode Fluorescent Lamp (CCFL) backlight system will be mounted on the ACOP front panel (TBC). This TFT-LCD has a 6.4 inch diagonally measured active display area with VGA resolution (640 vertical by 480 horizontal pixel array). Each pixel is divided into Red, Green and Blue sub-pixels or dots which are arranged in vertical stripes. A DC/AC inverter is installed inside to provide power for backlight tubes. Backlight tube brightness is adjustable by means of push buttons and software.

The following is a list of the hardware features for the LCD module (TBC).

- Compatible withVGA-480, VGA-400,VGA-350 and free format.
- Screen size 6.4"
- Display format 640xR,G,B x480
- Display colors: 262,144 colors
- Active area/Outline area =62.3%
- Backlight brightness is adjustable

LCD (TBC) display will be covered with a protection plastic cover (LEXAN) to avoid potential shatterable material hazard.

3.4.3.8   HARD DRIVES AND CARD CAGE ELECTRONICS

There are four hard drives installed in ACOP provide an estimated 20 days of recording. (Note: Dependent on event rate and size) The four installed hard drives will require periodic replacement by the ISS crew from the onboard stock of empty drives. A batch of 20 hard drives provides 150 days of recording capacity. New batches of hard drives will be delivered by STS and the original master copies of the AMS-02 data will be returned to earth by STS. A dedicated HDD Backplane provides blind mate connectors for the hard drives. Cable connectors are provided to bring the power and data to this backplane.

The following is a list of the hardware features for the Hard Disk Drives:

- Serial ATA with 1.5Gb/sec interface speed
- Native Command Queuing
- Build-in 16MB cache buffer
- Capacity 250 GB or Up

3.4.3.9   THERMAL SENSOR NETWORK

The thermal sensor network will consist of Dallas one-wire bus devices attached to a single network. The devices will be mounted where appropriate within the ACOP system. Each ACOP-10x board will have a front panel connector to connect the devices on it. Additionally several sensors will be mounted on the chassis to monitor base plate and hard drive temperatures. The digital I/O (DIO) function will be used to control this bus.

3.5   ACOP SOFTWARE

ACOP-SW is the entire body of embedded software running on the ACOP hardware. ACOP-SW consists of three components:
1) ACOP-SYS-SW providing low level functionality
2) ACOP-APP-SW providing the mission explicit application software functions on the ACOP hardware
3) ACOP-ERL-SW software developed by the ACOP project but which executes on the EXPRESS Rack Laptop

The S/W does not have any safety control and cannot produce an hazardous command or operation.

3.5.1 ACOP-SYS-SW

Implements the following main functions:

1. BootROM monitor providing boot strapping operations and low level file transfer functions.
2. Initialization of the ACOP hardware.
3. Operations of the ACOP hardware interfaces via device drivers.
4. Exception handling.
5. Diagnostic and system self-tests.
6. Management of data storage devices and file systems.
7. External command processing for system commands.
8. Execution and control of ACOP-APP-SW.

3.5.2 ACOP-ERL-SW

Implements the following main functions:

1. Implements a ISS crew interface on the EXPRESS Rack Laptop.

3.5.3 ACOP-APP-SW

Implements the following main functions:

1. Monitoring of resources and environment relevant to ACOP Health and Status.
9. Functional interfaces to ISS avionics C&DH systems.
2. Functional interfaces to the ISS HRDL interfaces.
3. Data recording.
4. Data playback.
5. Detailed data management.
6. Detailed management of data contents with regard to external systems.
7. External command processing for applications commands.

3.6   THERMAL SYSTEM

The "EXPRESS Rack" provides ACOP with the cooling air through ducted ports at the back plate of ACOP. The width and height of the two square ports of the inlet and the outlet for the ducted cooling air are 110 mm X 110 mm each one. The ports are fitted with screens, with an open area ratio of 60.02%, in order to filter the cooling air. A typical flow rate, 15+/-3 cubic feet per minute (cfm), of the cooling air with a normal operation pressure of 10.2 lb/in^2 (psia) is blown into the inlet of ACOP as described in the applicable reference [1]. See Figure 3-22.

On ACOP side two ducts are designed to connect the inlet and outlet ports with the fin channels as heat sinks extruded from the chassis of ACOP electronic modules in order to reduce the pressure loss. In case no duct is designed-in an abrupt expansion and contraction of the air flow would occur..

At both sides of the ACOP chassis, 56 fins are extruded respectively to be the heat sinks in order to increase both of the heat transfer area and the heat transfer coefficient of the cooling air. The thickness of the aluminium alloy fins is 1.5 mm with height and length of 60 mm and 162 mm respectively. The gap between two adjacent fins is 2.5 mm. See Table 3-2.

Table 1. Geometry of the fin channels of ACOP and the applied heat transfer coefficient h			
Number of fins at one side	**Thickness**	**Height**	**Length**
56	1.5 mm	60 mm	162 mm
Distance between two adjacent fins	**Value of h by a semi-empirical correlation**	**Value of h by the laminar flow model**	**Material**
2.5 mm	40.3 W/m^2°C	42.1 W/m^2°C	7075-T7351

Table 3-2: Geometry of the fin channels of ACOP and the applied heat transfer coefficient h

The effective hydraulic diameter of the fin channels is calculated to be 4.8 mm. Under this value of the effective channel diameter, the thickness of the thermal boundary layer of the fin wall can be reduced to be a small value such that for a constant Nusselt number of a laminar channel flow, the heat transfer coefficient h, inverse to the effective diameter, can be enlarged to a desired value around 40 W/ m^2°C. In addition to the increased heat transfer coefficient, the area for heat convection to the cooling air is also augmented significantly to decrease the systematically thermal resistance, leading to an apparent decrease of both of the boards and the parts working temperature.

The power dissipation is produced by every active part of each board in the ACOP electronic modules, including the four hard disk drivers. The power consumption in the form of heat conducts to the mounting board via the solder leads and the part case. The heat spreads to the board edge mainly via the copper layers implemented as the power and ground planes. Then, through the card-locker and the spacer fastening the boards to the inner side of the chassis, the heat conducts to the chassis. The fin channels extruded from the chassis absorb the heat to the surfaces. Finally the cooling air conveys away the heat via the forced convection.

The cooling air comes into the inlet, and passes through the filtering screen, and then is confined in and flows through the duct, and enters into the fin channels to take away the power dissipation, and comes out to the front chamber to cool the LCD panel, and then goes through the fin channels of the opposite side, and enters into the opposite duct and finally goes out to the Rack locker via the outlet port.
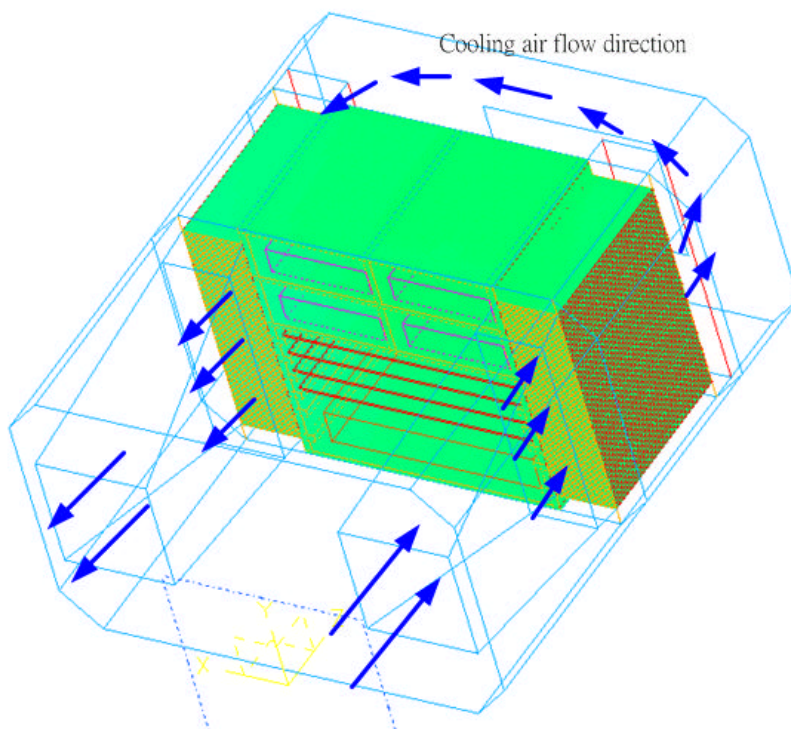

Figure 3-22: Flow direction of the supplied cooling air

4. OPERATIONAL SCENARIO

The Flight operation are here below listed:

4.1 LAUNCH PHASE

Nominally ACOP will be launched installed in a transportation rack within the MPLM (other transportation modes are foreseen including aft flight deck and ATV). ACOP is not powered and no hard drives are installed during assent. Hard drives, and other spare parts, are carried in a soft side stowage bag.

4.2 FLIGHT PHASE

Installation of ACOP inside An US-LAB ISPR
The ACOP will be installed into a US-LAB ISPR by the crew by securing the four captive bolts in the rear of ACOP to the EXPRES rack back plate. The launch locks on the front panel will be released and four hard drives installed.

External Cable Installation
The crew has to install the external cables that connect ACOP to the ISS: Power cable (to be connected to Jx of ACOP front panel see RD4) , HRDL cable (to be connected to Jy of ACOP front panel) and Data cable (to be connected to Jz of ACOP front panel)

ACOP POWER ON
Other then brief (less then 8 hours periods) of ISS low power modes and during hard drive exchange ACOP will be powered on. The Power On phase consists of putting ACOP's front panel circuit breaker in the "on" and verifying on the display that the booting phase of ACOP has finished successfully and ACOP is in the cold start mode (see below). ACOP's operational mode can then be selected by interaction with the command interfaces (either by the crew or ground.)

ACOP Power Off
Nominally ACOP is informed that it is being powered down. When so instructed it enters the Active Idle mode. Once this condition has been verified ACOP can be switched off.

HARD Drive Disks installation and Exchange
The ISS crew will be in charge of installation and exchange of hard drives. The operation will be made with ACOP powered down.

The crew has to:

1. Retrieve the appropriate ACOP storage bag.
2. Power down ACOP per 0above.
3. Open the LCD front panel by pulling the LCD front panel handle. The LCD font panel will remain in the open position thanks to a friction hinge.
4. HDDs already installed are removed and returned to the stowage bag.
5. Fresh HDDs will be inserted in the four slots present inside the ACOP and fixed with the card retainer: lever arm type card retainers will be used so no dedicated tools are required for this activity..
6. The crew will log the disk serial numbers of disks removed and installed.
7. Restore power and resume operation per 0above.
8. Re-stow the ACOP stowage bag.

4.2.1 OPERATIVE MODES

ACOP is primarily a ground operated system but can be crew commanded.

ACOP will have the following principal operating modes:

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	ACOP	Issue: 1	Date: Jan. '05
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CARLO GAVAZZI SPACE SpA

- Powered off
- Cold start
- Software upgrade (a special function of cold start)
- Warm start
- Active idle
- Active recording
- Active playback
- Active recording and playback

During any of the active modes ACOP can serve as a crew interface directing commands to AMS-02.

During any of the states other then powered off ACOP will accept ground commands.

5. FAILURE MODES, EFFECTS AND CRITICALITY ANALYSIS

5.1 GENERAL

The purpose of FMECA is to identify all failure modes of the system and rank them in accordance with the severity of the effects of their occurrence. Furthermore, it is to:
- identify possible failure modes and their possible effects
- determine the severity of each failure effect
- identify and possibly remove or control the Single Point Failures
- reduce failures causing outages or safety impacts
- identify requirements for controlling failure effects
- eliminate failure propagation
- validate and verify design redundancies.

5.2 RELIABILITY REQUIREMENTS

The ACOP reliability requirements are derived from [RD8].

5.2.1 CRITICALITY CATEGORIES

The following Reliability Categories, according to [RD8] and NSTS 1700.7B for safety categories [AD NASA 2], have been used:

Cat. 1a: *catastrophic*	(see applicable safety category)
Cat. 1b: *critical*	(see applicable safety category)
Cat. 2: *major*	The failure propagates across the interface and/or the facility cannot operate anymore.
Cat. 3: *significant*	The facility is partly operable (minor impact on the mission) or needs corrective on-orbit maintenance.

Items of criticality Category 1 failures which are not on-orbit maintainable, and all items with Category 2 failures shall be listed in a Single Point Failure (SPF) list.

5.3 ANALYSIS ASSUMPTION

The FMECA is based upon the design concept described in the section 3. The FMECA addresses the ACOP flight segment in all operation phases that are foreseen during the mission.
In this phase the analysis is performed only at level to the major functions of the identified subsystems developed by CGS. Only single failures are considered. No double failure is taken in account.

In the following table the identified ACOP functional blocks are reported.

UNIT/ASSEMBLY	ITEM NO.	ITEM/BLOCK	REFERENCE
	1.1	Main Memory SRAM 256MB	Figure 3-16
	1.2	AP Flash Memory 32MB	
ACOP-SBC	1.3	MicroProcessor IBM PowerPC750	
	1.4	Boot Flash EEPROM	

UNIT/ASSEMBLY	ITEM NO.	ITEM/BLOCK	REFERENCE
	1.5	North PCI Bus Bridge chip	
	1.6	Connectors	
	1.7	ACOP SW (SYS, APP) Note. Only the SW implemented in SBC has been considered in the analysis	
	1.8	Serial I/Fs Ports Note: I/Fs are used only for ground operations so they are not considered in this analysis	
ACOP-T101	2.1	Actel FPGA	Figure 3-17
	2.2	256kx32 ZBT SRAM (#2)	
	2.3	HRDL I/Fs Tx(#2)Rx(#1)	
	2.4	Connectors	
ACOP-T102	3.1	Actel FPGA	Figure 3-18
	3.2	256kx32 ZBT SRAM (#2)	
	3.3	VGA Level Shift	
	3.4	D/A Converter	
	3.5	DIO I/F	
	3.6	USB Controller (#2) Note: USB I/Fs are used only for ground operation. They should be used to update SW, if needed (TBC)	
	3.7	Connectors	
ACOP-T103	4.1	PCI to Ethernet Controller (#2 channels)	Figure 3-19
	4.2	PCI to Quad SATA Controller (#4 channels)	
	4.3	Connectors	
ACOP-PS	5.1	Circuit Breaker +28 V Note: function is the same of the items 8.4 and 5.7	Figure 3-21, Figure 3-13
	5.2	Input Emi Filter (#3) Note: as part of DC/DC Converters	
	5.3	Hybrid DC/DC Converter 12V	
	5.4	Hybrid DC/DC Converter 3.3V	
	5.5	Hybrid DC/DC Converter 3.3V	
	5.6	Spike and EMI Filter (#3) Note: as part of DC/DC Converters	
	5.7	Overload protections (Overvoltage/overcurrent/short circuit/overtemperature)	
	5.8	Connectors	
ACOP-BP	6.1	ACOP Backplane	Figure 3-20

UNIT/ASSEMBLY	ITEM NO.	ITEM/BLOCK	REFERENCE
HARD DRIVE	7.1	Hard Drive (#4)	Figure 3-7
Front Panel	8.1	HRDL Connector	Figure 3-8
	8.2	Power Connector	
	8.3	MRDL Connector	
	8.4	Circuit Breaker (switch)	
	8.5	LCD (TBC)	
	8.6	Push buttons. Note: At moment the function is not defined so the buttons are not considered in this analysis	
Mechanical	9.1	Mechanical Parts	Figure 3-4

Unit /Assembly: ACOP-SBC									
Operational Mode: --						Ref.: --			
						Operational Phase: Flight operations			
N°	**ITEM / BLOCK**	**ITEM**	**FUNCTIONAL BLOCK**	**ASSUMED FAILURE MODE**	**EFFECTS AT EQUIPMENT LEVEL**	**EFFECTS AT SYSTEM LEVEL**	**CR.**	**FAILURE DETECTION METHOD**	**PREVENTION OR COMPENSATION METHOD**	**REMARKS**
1101	Main Memory SRAM 256MB	1.1	To perform Program functions	Loss of read/write capability	Impossible to manage Loss of SBC functionality	Loss of ACOP functionalities	3	No data from ACOP	Corrective maintenance: SBC is an "On orbit replaceability item"	
1201	AP Flash Memory 32MB	1.2	To store main SW	Loss of function	Loss of main SW Impossible to manage the SBC	Loss of ACOP functionalities	3	No data from ACOP	Corrective maintenance: SBC is an "On orbit replaceability item"	
1301	MicroProcessor IBM PowerPC750	1.3	Central processing	Loss of function	Impossible to manage SBC Loss of SBC functionality	Loss of ACOP functionalities	3	No data from SBC	Corrective maintenance: SBC is an "On orbit replaceability item"	
1401	Boot Flash EEPROM	1.4	To contain the primary bootloader	Loss of function	Impossibility to load on-board SW Loss of SBC function	Loss of ACOP functionality	3	No data from SBC	Corrective maintenance: SBC is an "On orbit replaceability item	
1501	North PCI Bus Bridge chip	1.5	To provide the connections to the process memory	Loss of function	Impossible to manage SBC Loss of SBC functionality	Loss of ACOP functionalities	3	No data from SBC	Corrective maintenance: SBC is an "On orbit replaceability item"	
1601	Connectors	1.6	To provide Internal I/Fs	Short/open circuit	Loss of I/Fs Impossible to receive/transmit data/commands Loss of SBC functionality	Loss of ACOP functionality	3	Anomalous data from ACOP	Corrective maintenance: SBC is an "On orbit replaceability item"	
1602				Degraded contact	Receiving/transmission capability degradation	Loss of ACOP functionality	3	Anomalous data from ACOP	Corrective maintenance: SBC is an "On orbit replaceability item"	
1701	ACOP SW (SYS, APP)	1.7	To provide low level functionality (SYS)	Loss of function due to SW internal failure or program/data memory failure	Impossibility to load APP SW and/or to support some function of APP SW Loss of SBC functionality	Loss of ACOP functionality	3	No data from ACOP	Corrective maintenance: SBC is an "On orbit replaceability item"	

Unit /Assembly: ACOP-SBC						Ref.: --			
Operational Mode: --						Operational Phase: Flight operations			
N°	ITEM / BLOCK	ITEM	FUNCTIONAL BLOCK	ASSUMED FAILURE MODE	EFFECTS AT EQUIPMENT LEVEL	EFFECTS AT SYSTEM LEVEL	CR.	FAILURE DETECTION METHOD	PREVENTION OR COMPENSATION METHOD	REMARKS
1702			To provide the mission explicit application SW functions (APP)	Loss of function due to SW internal failure or program/data memory failure	Impossibility to perform data handling Loss of SBC functionality	Loss of ACOP functionality	3	No data from ACOP	Corrective maintenance: SBC is an "On orbit replaceability item" Reload SW trough USB (TBC)	

Unit /Assembly: ACOP-T101							**Ref.: --**				
Operational Mode: --							**Operational Phase: Flight operations**				
N°	**ITEM / BLOCK**	**ITEM**	**FUNCTIONAL BLOCK**	**ASSUMED FAILURE MODE**	**EFFECTS AT EQUIPMENT LEVEL**	**EFFECTS AT SYSTEM LEVEL**	**CR.**	**FAILURE DETECTION METHOD**	**PREVENTION OR COMPENSATION METHOD**	**REMARKS**
2101	Actel FPGA	2.1	To provide correct command and data exchange with SBC to manage T101	Loss of function	Impossible to provide commands and signals Loss of T101 functionality	Degradation of ACOP functionality	3	Anomalous data from ACOP	Corrective maintenance: T101 is an "On orbit replaceability item"	
2201	256kx32 ZBT SRAM (#2)	2.2	Buffer between system slot and FPGA	Loss of function	Impossible to provide correct commands and signals Degradation of T101 functionality	Degradation of ACOP functionality	3	Anomalous data from ACOP	Corrective maintenance: T101 is an "On orbit replaceability item"	
2301	HRDL I/Fs Tx(#2)Rx(#1)	2.3	To provide transmit (#2) and receive (#1) fiber optic I/Fs	Loss of function	Impossibility to transmit and/or receive ISS HRDL CCSDS packet data Loss of T101 functionality	Degradation of ACOP functionality	3	Anomalous data from ACOP	Corrective maintenance: T101 is an "On orbit replaceability item"	
2401	Connectors	2.4	To provide Internal I/Fs	Short/open circuit	Loss of I/Fs Impossible to receive/transmit data/commands Loss of T101 functionality	Loss of ACOP functionality	3	Anomalous data from ACOP	Corrective maintenance: T101 is an "On orbit replaceability item"	
2402				Degraded contact	Receiving/transmission capability degradation	Loss of ACOP functionality	3	Anomalous data from ACOP	Corrective maintenance: T101 is an "On orbit replaceability item"	

Unit /Assembly: ACOP-T102 — **Ref.: --**

Operational Mode: -- — **Operational Phase: Flight operations**

N°	ITEM / BLOCK	ITEM	FUNCTIONAL BLOCK	ASSUMED FAILURE MODE	EFFECTS AT EQUIPMENT LEVEL	EFFECTS AT SYSTEM LEVEL	CR.	FAILURE DETECTION METHOD	PREVENTION OR COMPENSATION METHOD	REMARKS
3101	Actel FPGA	3.1	To provide correct command and data exchange with SBC to manage T102	Loss of function	Impossible to provide commands and signals Loss of T102 functionality	Degradation of ACOP functionality	3	Anomalous data from ACOP	Corrective maintenance: T102 is an "On orbit replaceability item"	
3201	256kx32 ZBT SRAM (#2)	3.2	Video memory and Buffer between system slot an FPGA	Loss of function	Impossible to provide correct commands and signals Degradation of T102 functionality	Degradation of ACOP functionality	3	Anomalous data from ACOP	Corrective maintenance: T102 is an "On orbit replaceability item"	
3301	VGA Level Shift	3.3	To provide LCD graphic function (TBC)	Loss of function	Impossible to show data on display Degradation of T102 functionality	Degradation of ACOP functionality	3	Anomalous data from ACOP	Corrective maintenance: T102 is an "On orbit replaceability item" Use of laptop to show data	
3401	D/A Converter	3.4	To adjust brightness of theLCD backlighting	Loss of function	Low visibility data on display Degradation of T102 functionality	Degradation of ACOP functionality	3	Anomalous data from ACOP	Corrective maintenance: T102 is an "On orbit replaceability item" Use of laptop to show data	
3501	DIO I/F	3.5	To provide digital input/output I/F	Loss of function	Impossibility to use push buttons Degradation of T102 functionality	Degradation of ACOP functionality	3	Push Buttons Malfunctions	Corrective maintenance: T102 is an "On orbit replaceability item"	
3601	USB Controller (#2)	3.6	To provide USB I/F (#2)	Loss of function	Impossibility to update SW if needed trough laptop (TBC) Degradation of T102 functionality	Degradation of ACOP functionality	3	Anomalous data from ACOP	Corrective maintenance: T102 is an "On orbit replaceability item"	
3701	Connectors	3.7	To provide Internal I/Fs	Short/open circuit	Loss of I/Fs Impossible to receive/transmit data/commands Loss of T102 functionality	Loss of ACOP functionality	3	Anomalous data from ACOP	Corrective maintenance: T102 is an "On orbit replaceability item"	

Unit /Assembly: ACOP-T102   **Ref.: --**

Operational Mode: --   **Operational Phase: Flight operations**

N°	ITEM / BLOCK	ITEM	FUNCTIONAL BLOCK	ASSUMED FAILURE MODE	EFFECTS AT EQUIPMENT LEVEL	EFFECTS AT SYSTEM LEVEL	CR.	FAILURE DETECTION METHOD	PREVENTION OR COMPENSATION METHOD	REMARKS
3702				Degraded contact	Receiving/transmission capability degradation	Loss of ACOP functionality	3	Anomalous data from ACOP	Corrective maintenance: T102 is an "On orbit replaceability item"	

Unit /Assembly: ACOP-T103									
Operational Mode: --						Ref.: --			
						Operational Phase: Flight operations			
N°	ITEM / BLOCK	ITEM	FUNCTIONAL BLOCK	ASSUMED FAILURE MODE	EFFECTS AT EQUIPMENT LEVEL	EFFECTS AT SYSTEM LEVEL	CR.	FAILURE DETECTION METHOD	PREVENTION OR COMPENSATION METHOD	REMARKS
4101	PCI to Ethernet Controller (#2 channels)	4.1	To provide two Ethernet I/F controller ports	Loss of function	Impossible to transmit/receive data and/or to transmit commands Degradation of T103 functionality	Degradation of ACOP functionality	3	Anomalous data from ACOP	Corrective maintenance: T103 is an "On orbit replaceability item"	
4201	PCI to Quad SATA Controller (#4 channels)	4.2	To provide access to storage media as HDD	Loss of function	Impossible to transfer data Degradation of T103 functionality	Degradation of ACOP functionality	3	Anomalous data from ACOP	Corrective maintenance: T103 is an "On orbit replaceability item"	
4301	Connectors	4.4	To provide Internal I/Fs	Short/open circuit	Loss of I/Fs Impossible to receive/transmit data/commands Loss of T103 functionality	Loss of ACOP functionality	3	Anomalous data from ACOP	Corrective maintenance: T103 is an "On orbit replaceability item"	
4302				Degraded contact	Receiving/transmission capability degradation	Loss of ACOP functionality	3	Anomalous data from ACOP	Corrective maintenance: T103 is an "On orbit replaceability item"	

Unit /Assembly: Unit: ACOP-PS | **Ref.:**

Operational Mode: | **Operational Phase:**

N°	ITEM / BLOCK	ITEM	FUNCTIONAL BLOCK	ASSUMED FAILURE MODE	EFFECTS AT EQUIPMENT LEVEL	EFFECTS AT SYSTEM LEVEL	CR.	FAILURE DETECTION METHOD	PREVENTION OR COMPENSATION METHOD	REMARKS
5101	Circuit Breaker +28 V	5.1	To provide power to ACOP system	Fails to close	No 28V power supply to PS PS not working	Loss of ACOP functionality	3	Loss of data from ACOP	Corrective maintenance: PS is an "On orbit replaceability item"	Function is the same of the items 8.4 and 5.7
5102				Fails to open	Impossible to shut-off ACOP trough circuit breaker Increase in power consumption	Degradation of ACOP functionality	3	Loss of data from ACOP	Corrective maintenance: PS is an "On orbit replaceability item"	
5201	28 V Input EMI Filter (#3) (as part of DC/DC Converters)	5.2	Filtering of primary power noise and disturbance	Filter has open circuit	No 28V power supply to PS PS not working	Loss of ACOP functionality	3	Loss of data from ACOP	Corrective maintenance: PS is an "On orbit replaceability item"	One filter for each DC/DC
5301	Hybrid DC/DC Converter 12V	5.3	To provide 12V voltage conversion	DC/DC converter off	No 12V power supply PS board shutdown	Loss of ACOP functionality	3	Loss of data from ACOP	Corrective maintenance: PS is an "On orbit replaceability item"	
5401	Hybrid DC/DC Converter 3.3V	5.4	To provide 3.3V voltage conversion	DC/DC converter off	No 3.3V power supply PS board shutdown	Loss of ACOP functionality	3	Loss of data from ACOP	Corrective maintenance: PS is an "On orbit replaceability item"	
5501	Hybrid DC/DC Converter 5V	5.5	To provide 5V voltage conversion	DC/DC converter off	No 5V power supply PS board shutdown	Loss of ACOP functionality	3	Loss of data from ACOP	Corrective maintenance: PS is an "On orbit replaceability item"	
5601	Spike and EMI Filter (#3) (as part of DC/DC Converters)	5.6	Filtering of secondary power noise and disturbance	Filter has open circuit	No outlet power supply Degradation of PS functionality	Degradation of ACOP functionality	3	Loss of data from ACOP	Corrective maintenance: PS is an "On orbit replaceability item"	One filter for each DC/DC
5701	Overload protection	5.7	To detect the failure in case of overvoltage /overcurrent/short circuit/overtemperature condition	Loss of function protection	If failure occurs, the protection does not shutdown the DC/DC board	Loss of PS functionality and failure propagation to other subsystems / assemblies/equipment as second failure	3	None	None	Second failure required before failure has effect on performance (TBC)

N°	ITEM / BLOCK	ITEM	FUNCTIONAL BLOCK	ASSUMED FAILURE MODE	EFFECTS AT EQUIPMENT LEVEL	EFFECTS AT SYSTEM LEVEL	CR.	FAILURE DETECTION METHOD	PREVENTION OR COMPENSATION METHOD	REMARKS
5801	Connectors	5.8	To provide Internal I/Fs	Short/open circuit	Loss of I/Fs Impossible to provide power	Loss of ACOP functionality	3	Loss of data from ACOP	Corrective maintenance: PS is an "On orbit replaceability item"	
5802				Degraded contact	Power providing capability degradation	Loss of ACOP functionality	3	Loss of data from ACOP	Corrective maintenance: PS is an "On orbit replaceability item"	

Unit /Assembly: ACOP-BP — **Ref.: --**

Operational Mode: -- — **Operational Phase: Flight operations**

N°	ITEM / BLOCK	ITEM	FUNCTIONAL BLOCK	ASSUMED FAILURE MODE	EFFECTS AT EQUIPMENT LEVEL	EFFECTS AT SYSTEM LEVEL	CR.	FAILURE DETECTION METHOD	PREVENTION OR COMPENSATION METHOD	REMARKS
6101	ACOP Backplane	6.1	To provide mechanical and power I/Fs to PCI	Loss of function	Impossible to transmit/receive data and/or provide power Loss of PCI functionality	Loss of ACOP functionality	2	Loss of data from ACOP		

Unit /Assembly: ACOP-Hard Drive							Ref.: --				
Operational Mode: --							**Operational Phase: Flight operations**				
N°	ITEM / BLOCK	ITEM	FUNCTIONAL BLOCK	ASSUMED FAILURE MODE	EFFECTS AT EQUIPMENT LEVEL	EFFECTS AT SYSTEM LEVEL	CR.	FAILURE DETECTION METHOD	PREVENTION OR COMPENSATION METHOD	REMARKS
7101	ACOP hard drive (#4)	7.1	To provide data experiment recording	Loss of function	Impossible to record data	Loss of ACOP functionality	3	No data from ACOP	Corrective maintenance: HDD is an "On orbit replaceability item	
7102				High rotational speed	Impossible to record data	Loss of ACOP functionality Generation of brittle materials	1b	Visible damage	The Potential Hazard has been tracked in the Hazard Report ACP-STD-001 in the [RD16]	

Unit /Assembly: ACOP-Front Panel										**Ref.: --**			
Operational Mode: --										**Operational Phase: Flight operations**			
N°	**ITEM / BLOCK**	**ITEM**	**FUNCTIONAL BLOCK**	**ASSUMED FAILURE MODE**	**EFFECTS AT EQUIPMENT LEVEL**	**EFFECTS AT SYSTEM LEVEL**	**CR.**	**FAILURE DETECTION METHOD**	**PREVENTION OR COMPENSATION METHOD**	**REMARKS**
8101	HRDL Connector	8.1	To provide HRDL Interface	Loss of function	Impossibility to transmit and/or receive ISS HRDL CCSDS packet data	Degradation of ACOP functionality	2	Anomalous data from ACOP	None	
8201	Power Connector	8.2	To provide power I/F	Loss of function	Impossibility to provide power to ACOP	Loss of ACOP functionality	2	Loss of ACOP data	None	
8301	MRDL Connector	8.3	To provide data/command I/F	Loss of function	Impossibility to transmit/receive data and commands from/to ACOP	Loss of ACOP functionality	2	Loss of ACOP data	None	
8401	Circuit Breaker (switch)	8.4	To provide power to ACOP system	Fails to close	No 28V power supply to PS	Loss of ACOP functionality	2	Loss of data from ACOP	None	
8402				Fails to open	Impossible to shut-off ACOP trough circuit breaker Increase in power consumption	Degradation of ACOP functionality	3	Loss of data from ACOP	None	
8501	LCD (TBC)	8.5	To provide data display	Loss of function	Impossible to show data on display	Degradation of ACOP functionality	3	Anomalous data from ACOP	Data are shown trough laptop	
8502				Rupture	Impossible to show data on display	Degradation of ACOP functionality Generation of shatterable materials	1b	Visible damage	The Potential Hazard has been tracked in the Hazard Report ACP-STD-001 in the [RD16]	

Unit /Assembly: ACOP-Mechanical									**Ref.: --**	
Operational Mode: --									**Operational Phase: Flight operations**	
N°	**ITEM / BLOCK**	**ITEM**	**FUNCTIONAL BLOCK**	**ASSUMED FAILURE MODE**	**EFFECTS AT EQUIPMENT LEVEL**	**EFFECTS AT SYSTEM LEVEL**	**CR.**	**FAILURE DETECTION METHOD**	**PREVENTION OR COMPENSATION METHOD**	**REMARKS**
9101	Mechanical parts	9.1	To provide structural integrity	Rupture	Loosing of structural parts	Loss of ACOP functionality	1a	Visible damage	The Potential Hazard has been tracked in the Hazard Report ACP-HR-002 in the [RD16]	

6. SINGLE POINT FAILURE LIST

At PDR level In this phase the FMECA has been performed considering only the major functional of the ACOP.
The most identified failure modes are Severity Categories 3 because all CompactPCI (ACOP-SBC, T101, T102, T103), Hard Drives and the Power Supply (PS) are On orbit Maintenance Items.
 For the failures no. 7102, 8502, 9101 having Severity Categories 1a the Safety Hazard Analysis has been performed in order to identify the associated hazard and the adequate controls (Refer to [RD8]).
The Single Point Failure are the no. 6101, 8101, 8201, 8301, 8401 related to Backplane and Front Panel Items. At PDR level the relevant failure mode has been identified in general way as "loss of function"; deeper level analysis will be performed when the detailed design will be available.